NOTICE

U.S. Department of Transportation
Federal Aviation Administration

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SUBJ: ADDRESSING HUMAN FACTORS/PILOT INTERFACE ISSUES OF COMPLEX, INTEGRATED AVIONICS AS PART OF THE TECHNICAL STANDARD ORDER (TSO) PROCESS

1. PURPOSE. This notice provides guidance to facilitate the identification and resolution of human factors/pilot interface issues associated with complex, integrated avionics submitted for new or amended Technical Standard Order Authorization. This notice has three parts. The first is a suggested Federal Aviation Administration (FAA) process for evaluating the human factors/pilot interface avionics issues as part of the TSO process. The second is a discussion of some of the more prevalent, re-occurring human factors/pilot interface issues that have been observed during previous avionics TSO projects. The third is appendix 1, Part III: Summary of Human Factors Related Requirements & Recommendations, which contains requirements and recommendations extracted from TSOs and advisory circulars (ACs) to aid in issue resolution. Together these three parts will aid in the early identification and resolution of human factors/pilot interface issues, thus streamlining the certification process to avoid costly late system design changes.

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2. DISTRIBUTION. This notice is distributed to the branch level in Washington Headquarters Aircraft Certification Service, section level in all Aircraft Certification Directorates, all National Resource Specialists (NRS), all Aircraft Certification Offices (ACOs), and all Aircraft Certification Chief Scientific and Technical Advisors (formerly known as National Resource Specialists), Flight Standards District Offices (FSDO). Additional limited distribution should be made to the Air Carrier District Offices, the Aeronautical Quality Assurance Field Offices, and the FAA Academy.

3. THE TSO PROCESS AND HUMAN FACTORS CHALLENGES IN THE PROCESS.

a. TSO Authorization approval process. In the Technical Standard Order Authorization (TSOA) approval process, the applicant is responsible for reviewing the TSO requirements and submitting the applicable data to document compliance with the requirements, as specified in 14 Code of Federal Regulations (CFR) § 21.605(a). The FAA Aircraft Certification Specialist acting as the project manager is responsible for reviewing the TSOA package of documentation submitted by the applicant and determining compliance with the requirements (See 14 CFR Part 21, Subpart O and FAA Order 8150.1A, Technical Standard Order Procedures). The TSO review process presents two potential challenges from a human factors perspective, both of which will be addressed by this notice.

b. The first challenge. The current TSO review process does not ensure that the human factors/pilot interface issues are identified and addressed in a timely manner for complex, integrated avionics. This is, in part, because the TSOA process was originally developed for simple, stand-alone components, such as seat belts, ball bearings, and analog avionics such as audio amplifiers. For these types of components, the TSO process works relatively well because it is straightforward to specify the appropriate pilot interface/human factors design and performance requirements of simple components in the TSO. Thus, appliance or component level issues are adequately addressed in the TSO requirements and identified in a timely manner. The FAA role is simply to review the TSO documentation submitted by the applicant and address installation issues during the Type Certification (TC) or Supplemental Type Certification (STC) process.

(1) In contrast, avionics for which new TSOs are being published are substantially more complex, and the TSO process does not work as well to ensure pilot interface/human factors issues are identified and addressed in a timely manner. This is true for global positioning systems (GPS), traffic alert and collision avoidance systems (TCAS), and multi-function displays (MFD). (See also appendix 3 for a list of other equipment and systems considered to be complex, integrated avionics). The functionality of these systems directly affects, and can be affected by, other associated flight deck systems. Additionally, these new avionic systems typically have functionality well beyond those envisioned and specified in the TSOs.

(2) FAA Order 8150.1A specifies that when there is no TSO appropriate to a function of the system (e.g., a multi-function display with extra functionality not specified by the TSO), those additional functions "must be evaluated for safety and performance of its intended function under the appropriate airworthiness certification procedures when seeking aircraft installation approval." (See FAA Order 8150.1A, Section 18 d.(3)). These "unforeseen" functions are not addressed until the system is installed into an aircraft. Additionally, the implications to the pilot workload and task performance, for both the individual system and the flight deck as a whole, are not addressed until installation. Thus, with the continuous evolution of technology, it is difficult to foresee and specify the appropriate requirements for all potential functions of a system and its inter-relationships with other aircraft systems. Therefore, the current TSO process does not ensure that the human factors/pilot interface issues are identified and addressed in a timely manner for complex, integrated avionics.

(3) There are two different methods an applicant may pursue for obtaining the TSO and installation approval. The first method is where the applicant simultaneously seeks a TSO and an STC in order to obtain the TSO authorization and installation approval concurrently. In the second method, the applicant obtains the TSO authorization first, and later obtains installation approval subsequent to TSO issuance. Figure 3-1 shows the advantages and disadvantages associated with each method. Either method is acceptable. The FAA recommends the concurrent method for complex, integrated avionics in order to ensure the pilot interface/human factors aspects are adequately addressed in a timely and cost-effective manner.

FIGURE 3-1. COMPARISON OF THE PARALLEL VERSUS SEQUENTIAL TSO TC/STC PROCESS.

Approval Process	What The Process Entails	Advantages and Disadvantages
Parallel (also called Concurrent)	Applicant seeks TSO and STC simultaneously to get TSO Authorization and installation approval concurrently	Advantages: 1. Initial STC uncovers design issues with complex, integrated avionics. 2. Gives the FAA early opportunity to focus on aspects of design beyond that specified in TSO. 3. Maximizes opportunity for early feedback while avionics manufacturer is still involved. Thus, early changes can be cost effective.
Sequential	Applicant gets TSO Authorization first, then installation approval.	Advantages: 1. Avionics manufacturer only has to comply with TSO requirements. Little or no interaction with FAA. Disadvantages: 1. Defers evaluation of any part of design not addressed by TSO until installation approval during TC/STC process. This means any human factors/ /pilot interface evaluations of non-TSO features will not be addressed until the TC or STC. 2. Avionics changes may be difficult and costly, particularly because the avionics manufacturer may be out of the loop (not the installation applicant). Here the installer has little leverage with the avionics manufacturer to get the required changes made. 3. Required changes will be late and costly to the applicant (installer and avionics manufacturer).

(4) Since the initial STC typically uncovers design issues with complex, integrated avionics, particularly with features or functions not addressed in the TSO, it is typically beneficial for the applicant to concurrently seek a new or amended TSO Authorization during the TC or STC process. Such a request gives the FAA opportunities early in the design process to focus on aspects of the design beyond that specified by the TSO, particularly those related to integration and installation. This integrated review maximizes the opportunity for timely feedback early in the design process while the avionics manufacturer (TSO applicant) is still involved and able to make required changes. It is then possible and relatively cost effective to address identified issues.

(5) Regardless of the process chosen, the same review steps and evaluations apply. There will always be some human factors/pilots evaluations required for complex, integrated avionics at the time of aircraft installation and integration. The difference is that the concurrent TSO, TC, or STC process allows for a more timely and cost-effective identification and resolution of human factors/pilot interface issues.

c. The second challenge. Certification personnel have expressed a need for assistance in identifying human factors/pilot interface issues. This includes identifying areas where an article submitted for TSOA may not comply with the TSO requirements and guidance, and identifying issues with functions beyond those specified in the TSO. This is a serious challenge for both the applicant and the FAA. New TSOs are hundreds of pages long. Requirements are often spread across several different documents invoked by the TSO (e.g., multiple RTCA MOPS, SAE documents, ACs, etc.,). Thus, even when policy does address a given question or problem, it may be difficult to find.

(1) Relevant human factors/pilot interface policy may also be difficult to find because the human factors guidance may be associated with an entirely different system, not the one being approved. This is especially true for extra system functions beyond that specified by the TSO. Only the requirements in the TSO(s) the applicant requests are mandatory. Other TSOs may be used to identify and resolve issues.

d. In summary, these two challenges are particularly problematic for complex, integrated avionics submitted for TSO authorization. This notice focuses only on providing additional guidance specifically for complex, integrated avionics.

4. WHAT IS IN THIS NOTICE AND WHEN TO USE IT.

a. Part I of this notice contains new process guidance to meet the two challenges and ensure that the human factors/pilot interface aspects of complex, integrated avionics submitted for new or amended TSOA are addressed in a timely manner. The described process is not intended to add time or complexity to the certification process. It is simply intended to redistribute the avionics human factors review process so that some aspects of the review occur well before the flight test component of the STC. This approach complements "The FAA and Industry Guide to Avionics Approvals," dated April 2001 (See appendix 2), which recommends a TSO avionics approval process. This FAA and Industry Guide also addresses installation approval issues. The processes in both this notice and the FAA and Industry Guide are recommended, not required.

b. Part II features a discussion of key human factors/pilot interface issues seen in the field, those that are often overlooked, and those for which FAA policy has been routinely requested. These issues are grouped to keep related items together. Appendix 1 of this notice contains related requirements and recommendations. These requirements and recommendations were extracted from avionics TSOs and advisory circulars (ACs), as well as independent documents referenced in those TSOs and ACs, such as RTCA and SAE documents. Appendix 1 is not a comprehensive list of all human factors/pilot interface issues, requirements, or recommendations. This subset aids evaluation by members of the certification team to identify and resolve human factors/pilot interface issues.

c. Parts I and II should be used by the certification team projects with complex, integrated avionics submitted for new or amended TSOA. Part I should be used as a checklist to ensure that each of the process steps are completed by the appropriate party, i.e., applicant or the FAA. Part II should be used as a checklist when conducting human factors/pilot interface evaluations of the avionics.

5. PART I: RECOMMENDED STEPS FOR ADDRESSING HUMAN FACTORS AS PART OF THE TSO PROCESS.

a. The steps in figure 5-1 aid in identifying issues during the human factors/pilot interface evaluations early in the product development process. These steps may also be used to evaluate any additional system functionality beyond the functions, and associated requirements, specified in the TSO.

(1) The first column in figure 5-1 identifies some of the typical major steps in the TSO process for either a new or amended TSO, as documented in "Description of the FAA Avionics Certification Process," dated April 1997 (See Appendix 2). The second column lists recommendations to facilitate the timely identification and resolution of human factors/pilot interface issues.

(2) Not all steps of the TSO process are included below, only those for which a specific recommendation can be made. Items in the table below marked with an asterisk (*) are considered required as part of the current TSO process. All other steps are recommended. The steps appear as they would typically be done as part of a parallel or concurrent TSO and TC or STC project, which the FAA recommends. The applicant may choose to pursue the TSO and TC or STC sequentially.

(3) If the applicant chooses the sequential path, the same steps are recommended, although some of the steps and evaluations may be deferred until the installation approval is sought by the applicant. If deferred, any required changes are likely to be late in the program and costly to the applicant. In this case, it is important that the FAA and avionics manufacturer (TSO applicant) document what is done and not done as part of the TSO evaluation(s), so that appropriate credit can be obtained during the installation approval process. This documentation will also ensure that the issues and evaluations deferred earlier are addressed when the installation approval is requested.

FIGURE 5-1. TYPICAL AND RECOMMENDED STEPS TO FACILITATE THE EARLY IDENTIFICATION AND RESOLUTION OF HUMAN FACTORS/PILOT INTERFACE ISSUES.

Typical steps	Recommendations to facilitate the identification and resolution of human factors/pilot interface issues
1. Idea for new or changed avionics is born	
2. Informal discussions/phone calls with FAA to discuss potential certification of new avionics product.	• Applicant should communicate operational assumptions, what type of aircraft the avionics is intended to go into, etc. Generally, communicate project information that may help FAA identify potential certification issues. • FAA should provide, or indicate how to obtain, relevant reference material containing requirements and guidance. • FAA may also provide a list of other avionics previously approved or commercially available (non-proprietary) with similar features/functions that the applicant may consider and evaluate the pros and cons of their human-machine interface. This also provides an opportunity to take advantage of lessons learned.
3. FAA Pre-Familiarization meeting coordination	• FAA project manager should determine what FAA help is needed on the project (e.g., Chief Scientific and Technical Advisors (formerly known as National Resource Specialists), human factors, test pilots, software, etc.) • FAA project manager should distribute any project-relevant documentation submitted by the applicant to all FAA certification team members (see text associated with step 5 below for material that would be helpful to distribute). • FAA should consider cross-directorate or cross-ACO coordination. The ACO issuing the TSO should coordinate with the ACO responsible for first installation (note: the TSO and STC or TC may be requested through the same ACO or different ACOs).
4. Determine whether to do parallel TSO/STC or sequential	<u>Questions for FAA to ask applicant to help them decide which path to take</u>: • How complex or integrated is the system? • Any functions or features beyond that specified by the TSO? • Unique or novel technology or interface? Note: The FAA highly recommends the parallel TSO/STC process for complex and/or integrated systems with features beyond those specified by the TSO, especially for unique or novel interfaces.
5. Familiarization meeting	<u>Applicant should provide in advance of the meeting and also present at the meeting</u>: • Pictures, functional block diagrams, illustrations of displays & controls (both engineering and marketing). • Screen shots/prototype mock-ups of the display(s), flight deck installation location, etc.

FIGURE 5-1. TYPICAL AND RECOMMENDED STEPS TO FACILITATE THE EARLY IDENTIFICATION AND RESOLUTION OF HUMAN FACTORS/PILOT INTERFACE ISSUES (CONTINUED)

	• Step-by-step explanation of each feature and function along with the intended operational use and intended function. • Draft pilot/user interface description (documenting the features, functions, intended uses, etc.). • Emphasize outputs from the system to any other system or unique annunciators/alerts/switches/controls and all required sensor inputs to the system. • Design assumptions (target aircraft, intended pilot population, pilot training assumptions, intended function etc.). • Safety assessment considerations. • If software is involved, it may be helpful for the applicant to present a general idea of the software architecture. • Action items should be reviewed at the end of the meeting. Note: We recommend that the applicant be asked to document official meeting minutes and potential issues raised during meetings or evaluations. This will speed up the feedback process to the applicant, enabling them to start work immediately after the meeting to address issues raised, because they have immediate access to the draft notes. This is also beneficial because it entails minimal FAA effort, consistent with the TSO philosophy of placing the burden on the applicant in order to speed up the approval process. As a check-and-balance, the FAA members should take their own notes and validate the official notes submitted by the applicant, for completeness and concurrence. See AC 21-40 for guidance on documenting FAA meeting notes, action items, issues. Also see appendix 4 of this notice for a recommended approach to documenting certification issues and comments.
6. Post Familiarization meeting followup	<u>Applicant</u>: • Document how and when each human factors/pilot interface issue will be addressed (i.e., where in the TSO process or TC/STC process). • Submit issue resolution and note any design changes. <u>FAA:</u> Review and respond to proposed issue resolution and/or resolution process.
7. Initiate TSO project with ACO	Applicant should submit TSO Project Specific Certification Plan (PSCP) (see "<u>The FAA and Industry Guide to Avionics Approvals</u>" (April 2001) (See Appendix 2 for full reference)), or equivalent, which should document: • How and when each human factors/pilot interface issue will be addressed (i.e., in the TSO process, later in STC, etc.). The applicant may choose to submit this information in a separate human factors plan. FAA Policy Memo ANM-99-2,

FIGURE 5-1. TYPICAL AND RECOMMENDED STEPS TO FACILITATE THE EARLY IDENTIFICATION AND RESOLUTION OF HUMAN FACTORS/PILOT INTERFACE ISSUES (CONTINUED)

	"Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks," provides guidance for reviewing the human factors components of the certification plan, as well as what should typically be included in these plans to address the human factors issues in the intended installation aircraft. • Pictures, functional block diagrams, illustrations of displays and controls* • Explanation of each feature, intended operational use, and intended function * • Screen shots/prototype mock-ups of the display(s), flight deck installation location, etc.* • Draft pilot/user interface description • Design assumptions (target aircraft and/or multiple airframes, e.g., small helicopter vs. transport aircraft), intended pilot population, pilot training assumptions, intended function etc.)* • System Safety Assessment considerations, e.g., SAE Aerospace Recommended Practice (ARP) 4754 and 4761 and AC 2X. 1309* • List of TSOs being requested* • List of additional functionality of avionics not specified in the TSO(s) • TSO deviation requests * • Proposed evaluations necessary for any TSO deviations being requested to establish equivalent level of safety. • Proposed evaluations of any additional functionality of avionics not specified in the TSO(s) • Proposed method for showing compliance with the appropriate human factors/pilot interface related regulations, including, but not limited to 14 CFR §§ 23.1322, 23.1523, 23.777, 23.771 and so forth (or equivalent regulations in the appropriate part (25, 27, or 29)). Note: FAA Policy Memo ANM-99-2, "Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks," provides an appendix with a partial list of relevant human factors/pilot interface regulations. • May also include the applicant's process for folding back any issues that come up during evaluations into the design/re-design process. May also specify how this process will work once the system is fielded so that future design upgrades take into account feedback from operational use. (*Note: Items asterisked in this step are typically required to be submitted as part of the TSO data package)
8. FAA documentation	<u>FAA</u>

FIGURE 5-1. TYPICAL AND RECOMMENDED STEPS TO FACILITATE THE EARLY IDENTIFICATION AND RESOLUTION OF HUMAN FACTORS/PILOT INTERFACE ISSUES (CONTINUED)

review and internal coordination	• Review and provide comments on the Project Specific Certification Plan (PSCP) (or equivalent) • Based on the PSCP, determine if extra FAA help is needed on project (Chief Scientific and Technical Advisors (formerly known as National Resource Specialists) human factors, software, etc.) • Provide applicant with appropriate references (ACs, TSOs, etc.) • Provide AIR-130 with a "heads –up" notification on any TSO deviations.
9. Applicant conducts internal analyses/evaluations (validation of requirements & verification of performance of software and hardware) * • Demonstrate compliance with the human factors/pilot interface TSO requirements*	At this phase the applicant may work with the FAA to demonstrate and evaluate the extra functionality, beyond that specified in the TSO(s) being applied for. These evaluations may be done various ways including bench tests, palletization, etc. If the applicant seeks credit for any of these evaluations, the FAA project engineer should have confidence that the design is sufficiently mature. Additionally, the FAA project engineer needs to ensure that the applicant is adhering to the configuration control process identified in the PSCP. Additionally, we suggest that the applicant provide a draft of the proposed bench test/flight test plan. This will help the FAA flight test personnel (including flight test pilots and flight test engineers) focus on evaluating aspects of the system that may be evaluated on the bench. Also, it helps familiarize the flight test personnel with the scenarios they will need to conduct in flight. Finally, it helps them determine whether the proposed flight test plan will be sufficient to evaluate the system. This may also streamline the flight test evaluation.
10. FAA provide input	<u>FAA should identify human factors/pilot interface issues that</u>: • Have been evaluated and found to be acceptable • Require design changes and further evaluations • Must be evaluated during the installation
11. Applicant responds to issues and submit documented changes	• Applicant should document human factors/pilot interface issues identified by the FAA. • Submit disposition of documented issues including proposed resolutions, implement design changes, document those changes, and propose further evaluations if needed.
12. Reiterate steps 9, 10, & 11 until satisfied.	FAA project engineer must ensure that the applicant is adhering to the configuration control process identified in the PSCP. Formal FAA TC/STC flight testing may be initiated at this point if the applicant has chosen the concurrent process and has submitted the appropriate data.
13. Applicant formally	<u>Applicant provides:</u>

FIGURE 5-1. TYPICAL AND RECOMMENDED STEPS TO FACILITATE THE EARLY IDENTIFICATION AND RESOLUTION OF HUMAN FACTORS/PILOT INTERFACE ISSUES (CONTINUED)

submits to FAA: • Statement(s) of compliance * • TSO data package *	• List of additional functionality of avionics not specified in the TSO(s) • A human factors/pilot interface summary report documenting the results of any human factors/pilot interface evaluations of the extra functionality. Specifically, the report should document what evaluations were done, what features and functions were found acceptable, and identify those functions or features, which must be evaluated before the installation approval. This report should be formally submitted as part of the TSO data package as well as included in the installation instructions. Reference the section of this notice called "Documenting what was done and what was not" for additional guidance.
14. FAA must review data package and identify issues. Communicate issues (Note: No FAA involvement required according to Order 8151.1A until data package is complete. FAA must respond within 30 days). The applicant may chose not to have FAA involvement until this time. However, the FAA recommends the previous steps in advance of that to facilitate the process*	
15. Issue TSO Authorization	

b. Whichever approval process is chosen by the applicant, the following are general recommendations from the Certification Process Improvement document, which are likely to facilitate the process:

(1) Conduct early familiarization meeting(s) and document accordingly;

(2) Conduct meeting(s) using well-structured agendas/presentations, ensure key players attend, and document agreements, issues, and actions accordingly;

(3) Agree to clear timeframes, expectations, and action plans to accomplish all phases; and

(4) Produce timely, high quality documentation of decisions, agreements, schedules,

milestones, action item assignments, compliance/conformance submittals, and approvals.

c. During the familiarization and evaluation meetings, it is important that FAA participants distinguish between "wish list," or recommended design changes, and changes required for certification (i.e., either for the TSO or STC/TC approval). This distinction should be made when discussing the issues with the applicant and also in any meeting notes or issue papers resulting from system evaluations.

6. DOCUMENTING WHAT WAS DONE AND WHAT WAS NOT.

a. Human Factors Summary and Report. In the process recommended in paragraph 5 of this notice, several steps involve documenting what was done and not done, in terms of human factors/pilot interface evaluation. This section provides additional guidance on what should be documented, regardless of whether the applicant chooses the sequential path, or the concurrent/parallel TSO and TC/STC path. When the applicant chooses the sequential process, documenting the human factors/pilot interface evaluations is especially important to ensure that proper credit is given, where appropriate, for evaluations that might otherwise be deferred to the installation approval. We recommend that the evaluation methods, assumptions, and results be documented by the applicant using some form of summary or report.

b. Features and Functions to Document. This summary or report should specifically list any features or functionality of the component or system beyond that specified by the TSO. For each of the additional features or functions, the report should clearly document what, if any, evaluations were done of those features or functions, evaluation methods, assumptions, and results. This approach can benefit both the applicant and the FAA, because certification credit may be given for evaluations done by the FAA during the TSO process, and it will be clear which aspects of the design must be evaluated by both the applicant and FAA upon installation and integration. Additionally, this documentation minimizes potential misunderstandings by documenting key assumptions, evaluation procedures, and results. This documentation should be included as part of the TSO data package.

c. Elements to Include. The applicant should identify the Summary of Human Factors Evaluations and Results Report as part of the human factors/pilot interface activities in the PSCP. FAA Policy Memo ANM-99-2 provides guidance for reviewing the human factors components of the certification plan for transport category airplanes, as well as what should be included in these plans. To address the human factors/pilot interface issues of complex, integrated avionics submitted for TSO Authorization approval, the following guidance supplements Policy Memo ANM-99-2. A typical Human Factors Evaluations and Results Report should include the following elements:

(1) Product Description. The report should contain a detailed description of the product, including the annunciation, control, and display requirements specified in the TSO, a detailed list of all system functionality with an indication of any functionality not covered under the TSO(s) being sought. The target aircraft environment and type, as well as the intended operational environment should also be included.

(2) Software Level. The report should clearly identify all levels of software assurance, which must correlate with the System Safety Assessment (SSA).

(3) Safety Considerations. The report should document the assumptions and rationale used to establish the hazards associated with the product and its proposed installation. The hazard levels assumed for a function failure condition, and misleading display of information, if applicable, should be clearly documented for each function. Pilot procedures and limitations should not be used to mitigate these hazard levels.

(4) Method of Evaluations. The report should clearly identify the methods used for evaluating the flightcrew interface aspects of the product, the list of all functions, and the set of evaluation test scenarios. Policy Memo ANM-99-2 outlines some of the acceptable evaluation methods. These include, but are not limited to, bench tests, mock-up evaluations, part-task evaluations, simulator evaluations, ground test evaluations, and in-flight evaluations. One additional in-flight evaluation method, discussed below, is a palletized avionics evaluation. For this type of evaluation the applicant may install the displays in the aircraft in a test and evaluation avionics rack in the aft cabin area, not in the flight deck. While this is not necessarily as effective as the more typical flight test evaluations (i.e., where the system is installed in the flight deck) at identifying and resolving human factors/pilot interface issues, applicants are increasingly using the palletization method. This method is discussed here because its increasing popularity results in the need for guidance on using this method as a human factors/pilot interface evaluation tool, and also because all other methods are discussed elsewhere (see Policy Memo ANM-99-2). Palletized evaluations:

(a) Involve reviews of prototyped or developmental avionics installed on pallets or racks outside of the aircraft's flight deck, but located within the cabin.

(b) May be for informal feedback or for formal credit.

(c) Can be configured in a partial or full aircraft integrated fashion.

(d) Must ensure that the avionics being evaluated interfaces with the actual airplane sensors and aircraft power intended to be used in a typical installation, to qualify for any installation credit.

(e) Are not sufficient for reviewing some installation dependent features, such as cross flight deck visibility, aural alerts and annunciations, placement, accessibility of controls, and so forth.

(5) Acceptable Features and Functions. The report should clearly document the features and functions found acceptable by the FAA, including conditions and assumptions used to evaluate those features and the date and configuration or version number evaluated.

(6) Unacceptable Features and Functions. The report should document the issue(s) found unacceptable. While the applicant should resolve these issues before the TSO is issued, in some cases they may choose not to. They may choose to defer issues associated with features or functions that are not addressed by the TSO requirements until the installation approval is sought. For example, many TSOs do not contain viewing angle requirements. During evaluations, it may become apparent that the viewing angle would not be acceptable for a particular aircraft installation location. In this case, it would be acceptable to issue the TSO, but document the viewing angle issue which would have to be re-evaluated by the FAA during the installation approval process and addressed at that time. Therefore, it is important to document

these issues in the installation instructions in order to ensure that they are addressed prior to the installation approval. In some cases, it may be appropriate to include limitations in the installation instructions.

(7) Features and Functions Not Evaluated. The report should clearly document the features and functions not evaluated and identified which must be evaluated as part of the installation approval process. These un-evaluated features and functions should be documented in the installation instructions, which may also include installation limitations.

c. Configuration Control. Since FAA conformity requests are not used in the TSO approval process, when conducting a human factors/pilot interface evaluation on new or modified TSO equipment, the burden of configuration control must fall on the TSO manufacturer. Accurate configuration control is important to give the TSO manufacturer appropriate credit for the system evaluator's findings, or if the Summary of Human Factors Evaluations and Results Report is to have any follow-on value to the installer of the TSO-approved equipment. For example, make and model for the interfaced sensors should be included. A written request by the applicant for evaluation of the human factors/pilot interface aspects should define the configuration, the features intended to be evaluated, and the proposed means of conducting the evaluation. Additional guidance is in Order 8110.4B, Type Certification. This guidance addresses various steps in the TC and STC process, including the need for conformity requests, issuance of Type Inspection Authorizations (TIAs), required flight tests, and reporting of results in a Type Inspection Report (TIR). Some of the same steps could be considered appropriate for TSO projects.

(1) If the applicant proposes a FAA flight evaluation using a palletized temporary installation or prototype flight deck installation, the aircraft must have a special airworthiness certificate in the experimental category for showing compliance with regulations (21.191(b)) because of the unapproved equipment. The evaluation must adhere to the flight test risk management requirements of Order 4040.26A, Aircraft Certification Service Flight Safety Program, dated March 2001. The FAA project engineer and test pilot and/or flight test engineer should make the risk assessment and prescribe mitigations if needed. FAA will issue a Letter Of Authorization (LOA) as approval to conduct the evaluation and document the risk assessment. Signature authority for the LOA and risk assessment should be per the ACO's delegation authority and the requirements of Order 4040.26A, respectively.

(2) In the sequential process where the applicant initially seeks only the TSO but still conducts some FAA human factors/pilot interface evaluations, a Type Inspection Authorization (TIA) is not needed if it has been replaced by FAA acceptance of the details in the TSO applicant's request for evaluation and the configuration definition. FAA flight test personnel should conduct the evaluation. The FAA project engineer and test pilot should make the risk assessment, prescribe mitigations, if needed, and document them in the response to the applicant's evaluation request. Observance of the flight test risk management process defined in Order 4040.26A is required. A Special Project's TIA or LOA should then be issued to authorize FAA personnel to participate in the flight test evaluations. If operational issues will be affected (i.e. if the applicant wants to obtain operational credit for using the avionics), then an Aircraft Evaluation Group evaluation from Flight Standards must be involved.

d. The results of the FAA human factors/pilot interface evaluation should be included in the Human Factors Summary and Report submitted as part of the TSO data package.

7. PART II: HUMAN FACTORS/PILOT INTERFACE ISSUES.

a. Common and Problematic Issues. Historically, certification teams have noted a number of reoccurring human factors/pilot interface issues during the review of new digital avionics. This section helps standardize the identification and resolution of some common human factors/pilot interface issues. A subset of requirements and guidelines associated with the issues identified below is contained in appendix 1.

b. The human factors/pilot interface issues are organized into the following eight areas:

- Use of color
- Symbology
- Labels
- System Status Indications, Annunciations, & Messages
- Controls (knobs, buttons, cursor control devices, etc.)
- Display Placement & Readability
- Warning, Cautions & Alerts
- Error Prevention, Detection, & Recovery

c. The discussion of each of these eight issues starts with an introduction of factors associated with the topic, including potential implications associated with pilot performance and safety, followed by a list of key reference documents. For a complete list of all documents referenced in this notice, see appendix 2.

8. PART II: USE OF COLOR.

a. Background.

(1) Approximately nine percent of the population has some sort of color vision deficiency (what is commonly called "color blindness"). As of December 31,1998, there were a total of 16,493 male and 47 female active airmen with defective color vision (reference Aeromedical Certification Statistical Handbook Table V.C.). Of these, 2,317 held first class medicals, 3,871 held second class medicals, and 10,352 held third class medicals[1]. It should also be noted that the FAA does not test for all potential color deficiencies.

(2) As we age, our ability to discern colors degrades. Even before the age of 40, the cells in the eye that respond to color become less sensitive and the lens of the eye begins to yellow. As the lens yellows, light blues will appear whiter (see Cardosi & Hannon, 1999). Color can greatly improve display usability and effectiveness. However, great care must be taken when choosing a color philosophy and applying it to a system. Below is a discussion of some of the more problematic issues with color.

b. Prominent Use of Color Issues

(1) Applicants typically do not consider the proportion of the pilot population that is

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[1] These figures are based on active airmen certified within the previous 25 months and the assignment of the restriction "Not Valid for Night Flying by Color Signal Control" or issuance of a waiver for deficient color vision.

colorblind or color deficient. To address this, several new TSOs have included a requirement that information be coded using a minimum of two coding techniques that may include color, shape, and location. Use of redundant coding techniques will allow color deficient pilots to extract the relevant information from the display more easily. Additionally, research data indicates that redundant coding improves recognition, identification and interpretation of displayed information for all users, and not just those who are color deficient. Thus, redundant coding is highly recommended for all displayed information.

(2) A pervasive issue seen across multiple avionics submitted for approval is the inappropriate use of color. Most typically, applicants use the color red for items that may not require immediate corrective action. Amber is often used inappropriately for items that do not have the possible need for future corrective action, despite the regulatory requirements and advisory circular guidance on the appropriate uses for these colors. This is particularly problematic given the cultural importance of red and yellow or amber. Human factors data corroborates the assertion that the inappropriate use of these colors may systematically desensitize pilots to their meaning, so that pilots may not respond appropriately to a situation that requires immediate corrective action.

(3) The more sophisticated, higher quality color displays are able to display a myriad of colors with excellent fidelity. With this added capability, some applicants are using a large number of different colors on a single system. The use of many different colors on a single display can decrease the effectiveness of the display. Industry has generally recommended that no more than six colors be used for a single application. This recommendation is not applicable to electronic map displays where color is used to depict subtle terrain features or for applications where color has been used to add texture.

(4) There have been a number of applications incorporating colors not easily differentiated from one another, particularly when viewed off angle. Care should be taken to select colors that are sufficiently different from one another to permit ready discrimination for all intended installation and environmental conditions.

(5) Designers need to take special precautions when using color on displays. By specifying colors that provide maximum discrimination and by using these colors according to specified guidelines (such as use of redundant coding), the probability of misinterpretation can be significantly reduced.

c. See appendix 1, section 2: "Use of Colors" for requirements and guidelines.

d. Key References

(1) DOT/FAA/AR-99/52, Guidelines for the Use of Color in ATC Displays, Cardosi & Hannon, 1999. Cambridge, MA: Volpe National Transportation Systems Center.

(2) RTCA DO-256, Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A,. Section 2.1.3.6, "Color," dated June 20, 2000.

(3) 14 CFR. §§ 23.1322, 25.1322, 27.1322, and 29.1322, "Warning, Caution, and Advisory Lights."

(4) DOT/FAA/RD-95/1, "Guidelines for the Design of GPS and LORAN Receiver Controls and Displays," Michael D. McAnulty, March 1995.

(5) AC 25-11, "Transport Category Airplane Electronic Display Systems," dated July 16, 1987.

(6) AC 23.1311-1A, "Installation of Electronic Displays in Part 23 Airplanes," dated March 13, 1999.

(7) AC 27-1B, "Certificate of Normal Category Rotorcraft," AC Paragraph 27.1322, latest revision.

(8) AC 29-2C, "Certification of Transport Category Rotorcraft," AC Paragraph 29.1322, lastest revision.

(9) SAE Aerospace Recommended Practice 4032, "Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays," April 1988.

(10) SAE Aerospace Recommended Practice 4102 Core Document, "Flight Deck Panels, Controls and Displays," July 1988.

(11) DOD CM-400-18-05, Department of Defense User Interface Specifications for the Defense Information Infrastructure. Defense Information Systems Agency, February 1998.

9. PART II: SYMBOLOGY.

a. Background. For the purposes of this document, the word "symbology" is defined as a set of symbols used in a system. Symbology use has proliferated as display capability and the need to display more information in a given area has grown. The number of symbols used in a system continues to grow with each new development. Due to the mix of avionics on most flight decks, it is common to see the same symbol used to depict two different situations on a given flight deck. The large number of symbols and multiple use of some symbols on some flight decks significantly increase the likelihood of interpretation errors, which could lead to an inappropriate pilot action.

b. Prominent Symbology Issues

(1) In some applications, electronic symbols have been selected that are inconsistent with paper charts, other flight deck symbology, and common aviation practice. This forces pilots to learn new symbols, which may share some of the same symbology with other systems on the flight deck, but mean something different for that application. This increases the potential for confusion and misinterpretation. See appendix 6 for industry symbology standards for navigation aids.

(2) In some applications, applicants selected symbols that are not distinctive, they are not easily discernable from other symbols on the display. This is even more of a problem with symbols that are very similar to one another (i.e., distinguishing features may be very small or not easily noticed). In this case, symbol differences that are obvious when close-up may not be

obvious at greater distances, such as the distance of the display in a typical aircraft installation. Both situations increase the likelihood that symbols will be misinterpreted, particularly when those symbols are not readily differentiated from other symbols on the display and pilots only take a quick look. This problem is further exacerbated in certain viewing conditions such as off angle or in poor light. Another issue is symbols rotating when they should not, or not rotating when they should.

(3) Display quality and characteristics can significantly affect symbology readability and acceptability. Displays with less resolution cannot always accurately portray some complex symbols. Also, due to display hardware limitations, off-center viewing of symbology may be adversely affected. Display limitations have also adversely affected symbology readability under different lighting conditions.

c. See appendix 1, issue 3: Symbology for requirements and guidelines.

d. Key References

(1) FAA TSO C147, "Traffic Advisory System (TAS) Airborne Equipment," dated April 6, 1998.

(2) SAE Aerospace Recommended Practice 5289, "Electronic Aeronautical Symbols," October 1997.

(3) RTCA DO–185A, "Minimum Operational Performance Standards for Traffic Collision Avoidance System II (TCAS II) Airborne Equipment" dated December 17, 1998.

(4) RTCA DO-256, "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," Section 2.1.3.1, "Symbology," dated June 20, 2000.

10. PART II: LABELS.

a. Background

(1) Regulations require that each cockpit control, other than controls whose function is obvious, must be plainly marked as to its function and method of operation (i.e., 14 CFR § 25.1555(a) as well as equivalent wording in §§ 23, 27, and 29). As the number of separate controls on the flight deck grew, due to the incorporation of additional complex aircraft systems, so did the number of labels. Creative approaches were used to reduce the length of the labels, yet still communicate the function of the control. The impact of these creative labeling conventions was that pilots had to memorize numerous abbreviations, acronyms, and labels that do not seem to have anything to do with the associated function. Advanced technology has provided an answer to the labeling problem: labeling with icons and multi-function controls.

(2) In the latest generation of aircraft flight decks, manufacturers significantly reduced the number of separate controls on the flight deck by incorporating multifunction controls. For these systems, a single device controls several different systems and/or functions. This greatly reduces the number of controls on the flight deck, but there are some definite drawbacks. It may not be obvious to the pilot which system or function is being controlled, thus increasing the probability

that the pilot may inadvertently provide an input to the wrong system. An additional issue is with the location and type of labeling for the multifunction control device (e.g., cursor control device).

b. Prominent Label Issues

(1) There have been many cases where labels used in the aircraft differed from the labels in the user documentation. This can be particularly confusing when attempting to address a system problem or perform a checklist.

(2) Manufacturers have increased the use of unconventional labels. In some cases, increased display capacity has fostered the inclusion of additional letters to make the label more intuitive, yet resulting in a new abbreviation for pilots to remember. For example, instead of using the common label "ACK" for acknowledge, the applicant may include an additional letter (because the display allows four letters), resulting in the label "ACKN". Use of common terminology for labels is important, particularly when ICAO has an approved abbreviation or acronym, as it does for "acknowledge" which is "ACK". Furthermore, if the pilot is accustomed to the label "ACK" and it is used elsewhere on the flight deck except for this one system, then using anything other than this convention could lead to confusion.

(3) With the advent of electronic map displays, flightcrews are using paper charts less often. Pilots use paper charts to confirm information presented on the display. Unfortunately, it is not uncommon to see labels on the electronic map displays that differ from the charts.

(4) Many aviation equipment manufacturers are not aware that there is guidance for abbreviations and acronyms. For some systems, there are specific labeling conventions that must be followed. FAA personnel should determine whether there are any specific requirements for the system, and if not, direct the applicant to the guidance and references contained in appendix 7.

c. See appendix 7 and also appendix 1, Issue: Labels for requirements and guidelines.

d. Key References

(1) International Civil Aviation Organization (ICAO) 8400/5. "Procedures for Air Navigation Services ICAO Abbreviations and Codes." Fifth Edition- 1999.

(2) RTCA DO-256 "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," Section 2.1.3.5 "Labels," dated June 20, 2000.

11. PART II: SYSTEM STATUS INDICATIONS, MODES, ANNUNCIATIONS, AND MESSAGES.

a. Background

(1) Nearly every system on the flight deck has associated indications, annunciations, and status messages which pilots must monitor and understand. Designers of modern flight decks have often integrated these feedback mechanisms into fewer, less complicated messages;

however, much more needs to be done.

(2) This is a particular problem for older flight decks that have a mix of avionics systems installed. System limitations may restrict system feedback options, forcing the installation of separate annunciators and display devices, or tailoring messages to match system capabilities. Also, space limitations may force installers to place feedback mechanism in less desirable locations. As more complex and sophisticated systems are developed and integrated into older flight decks, the need for closer scrutiny and evaluation has become more essential.

(3) This notice does not address autopilot/autoflight modes.

b. Prominent System Status Indications, Modes, Annunciations, and Messages Issues

(1) In recent years, a new philosophy of flight deck design has emerged, namely, the "quiet, dark cockpit." Under this philosophy, system functioning, control selections and other aspects in the cockpit that are considered "normal" are not annunciated or otherwise indicated. According to this philosophy, if pilots scan the cockpit and see nothing illuminated, they can assume that everything is all right. The problem with these configurations is that it may not be obvious to the pilot what the "normal" situation or condition is for that system, and thus pilots must do something (e.g., select a system) just to reaffirm whether it is on or off. Applicants should be reminded that even for these designs, the flight deck should be designed to allow crews to work without unreasonable concentration or fatigue. This may require that some system feedback be given even for "normal" conditions.

(2) In some applications, the feedback message that a system is operating normally, performing some specific function, or malfunctioning, is not clear. Pilots have been forced to memorize the meaning of these sometimes drastically abbreviated or encrypted messages, or consult operator manuals to decipher messages. Messages should be constructed in an easy-to-interpret format with sufficient information to ensure understanding. The incorporation of different avionics systems into existing flight decks can be particularly challenging. One example is a case where the annunciators were initially installed in locations not clearly visible to the flight crew. Additionally, system status messages or other feedback mechanisms may be installed remotely from their associated system controls and displays, increasing the probability of pilot error.

(3) Integrated control/display systems with complex, multilevel control functions can make it difficult to access system status information. These systems may include several menu tiers that must be accessed to call up particular system information. With these systems, pilots must remember which menu items are associated with a given system to effect the selection.

(4) A good motto to follow is that, "it is ... better ...to put knowledge in the world than knowledge in the head," (Donald Norman, The Design of Everyday Things, 1989). In other words, it is better to put information on the display so the pilot doesn't have to remember it.

c. See appendix 1, issue 4: System Status Indications, Modes, Annunciations, and Messages for requirements and guidelines.

d. Key References

(1) RTCA DO –256, "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," dated June 20, 2000. Section 2.1.5 "System Status, Mode Annunciators & System Failure."

(2) RTCA DO-256, "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," dated June 20, 2000. Section 2.1.7.2 "Message Display and Formatting."

(3) Wickens, Christopher D., "Engineering Psychology and Human Performance; (2d ed.)," New York: New York, 1992.

(4) Salvendy, G. (ed.), "Handbook of Human Factors and Ergonomics," New York: Wiley, 1997.

12. PART II: CONTROLS.

a. Background

(1) Controls provide the primary system interface for inputting data and selecting system options. The number of controls on the flight deck has grown over the years. It is not unusual for a modern flight deck to feature over 200 controls. Well-designed and placed controls are an absolute necessity to the safe operation of an aircraft. Conventional aircraft control devices include knobs, buttons, levers, switches, wheels, and keyboards. Other control devices becoming more frequent in aircraft include joysticks, touch pads, trackballs and even devices similar to the commonly used computer mouse.

(2) Industry and the military have developed guidance on the design and operation of controls. The FAA provides little guidance in this area, as it is not the FAA's role to prescribe design. The FAA role is to ensure a minimum level of safety is maintained and that the minimum requirements are complied with. Typically, control access and use are addressed during the minimum flightcrew evaluation required to show compliance to 14 CFR §§ 25.1523, 23.1523, 27.1523, and 29.1523. Unfortunately, these evaluations are normally conducted late in the program when changes are more difficult and costly.

b. Prominent Controls Issues.

(1) Early evaluation of controls. The prevalence and availability of aviation controls have caused some disregard for their design and operation characteristics. It is common for system designers to select off-the-self controls for a system without considering the appropriateness and usability of the control for a given application. Consider the unique control requirements for each new system. The applicant and the FAA should evaluate controls early in the development process to ensure that selected controls will meet TSO and regulatory design and performance requirements.

(2) Controls too close together. The limited instrument panel space forces designers and installers to make compromises when locating controls. Human factors/pilot interface issues that result may include controls that are installed so close to one another that it is difficult to operate one control without inadvertently operating another. Additionally, unrelated controls may be collocated in an area of a panel, leading delays in response time to find the appropriate control,

increased workload, potential pilot errors, and potential confusion

(3) Cursor Control Devices (CCDs). The development and increasing use of CCDs pose some unique challenges. CCDs permit the user to perform a wide variety of control operations through a single device. A human factors/pilot interface issue with these types of control devices is that it may not be obvious which of the control functions are active. Pilots must be able to quickly and reliably identify the current active control function. Additionally, it must be possible to perform tasks to the same performance standards as from the use of conventional controls.

c. See appendix 1, issue 5: Controls, for requirements and guidelines.

d. Key References

(1) RTCA DO-256, "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," Section 2.1.1, "Controls," and Section 2.1.2.2, "Operation of Controls," dated June 20, 2000.

(2) DOT/FAA/CT-96/1, "Human Factors Design Guide for Acquisition of Commercial Off-The-Shelf Non- Developmental Systems and Developmental Systems." Joseph A. Birt, January 15, 1996.

(3) Schneiderman, B., "Designing the User Interface: Strategies for Effective Human-computer Interaction (3rd ed.)." (Chapter 9) Reading, MA: Addison Wesley, 1998.

(4) Bullinger, H. J., Kern, P., Braun, M. "Controls. In Salvendy, Handbook of Human Factors and Ergonomics," (2nd ed., pp. 697-728). New York, NY: Wiley & Sons, 1997.

(5) Greenstein, J.S. and Arnout, L. Y., "Human factors aspects of manual computer input devices." Chapter 11.4 in G. Salvendy (ed.), Handbook of Human Factors and Ergonomics (2nd ed., pp. 1451-1489), New York: John Wiley & Sons, 1987.

13. <u>PART II: DISPLAY PLACEMENT AND READABILITY</u>.

a. Background

(1) In the past, there were separate, individual analog instruments for each system. This resulted in instrument panels covered from one side to the other in small round dials. The introduction and use of digital electronic display systems provided opportunities to significantly change and improve display readability and usability. Initially, many designers simply developed display formats that mimicked the analog instruments they replaced. Later designs implemented vertical tapes with predictive information.

(2) On early digital electronic display systems it was sometimes difficult to see and read information, particularly in bright light. In recent years, display technology has progressed significantly. There are displays available today that provide a clear, crisp and readable presentation under nearly all possible lighting conditions. However, many of these advanced technological systems are still too expensive to be used in all facets of aviation.

b. Prominent Display Placement and Readability Issues

(1) The limited real estate available on flight deck instrument panels has forced some compromises when integrating and installing new systems. In some cases, displays have had to be placed in locations outside of the pilot's normal viewing area. This can significantly affect display effectiveness and readability. Some displays cannot be read well when viewed off angle. Also, displayed colors viewed off angle may appear different. Evaluations should be conducted to determine whether, and how much display usability and readability is degraded. Additionally, since most pilots wear sunglasses when flying in bright sunlight, consideration should be given to the readability of the displays under these circumstances. If appropriate, document installation limitations in TSO data package and also in the TSO installation instructions.

(2) Reflections and filters. Reflections are caused by light from external sources, reflected off the display surface. All displays reflect some external light. There are, however, many factors that affect reflections. Display manufacturers have done much to reduce reflections by using different materials and textures in display glass. Also, display filters have been effective in reducing reflection. The location of the display relative to the viewer and other items on the flight deck can significantly affect the presence and obtrusiveness of reflections. Evaluations should be conducted to determine whether installation limitations should be required for a particular display system.

c. See appendix 1, issue 7: Display Placement and Readability for requirements and guidelines.

d. Key references

(1) RTCA DO-256, "Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds 1 and 1A," Section 2.1.3.5 "Labels," dated June 20, 2000.

14. <u>PART II: WARNING, CAUTION, AND ADVISORY</u>.

a. Background

(1) An outgrowth of the greater number of systems on modern aircraft is the proliferation of warnings, cautions and advisories on the flight deck. For most systems, pilots need immediate feedback when a system is malfunctioning or has failed. To address this, designers developed annunciator panels that contained all the systems' warning, caution and alert information in one display. Individual color-coded legend lights would illuminate when a system malfunction or failure was detected. The pilot could see at a glance which system had experienced the problem. In some later designs, master warning and caution systems were incorporated to ensure pilot awareness of the situations that may require immediate pilot action.

(2) Most modern aircraft have incorporated warning, caution, and alert information in multifunction electronic displays. Usually a specific area of the display is dedicated to present this information. Since these systems typically display engine and instrument conditions, the term EICAS (engine/instrument caution advisory system) has been coined. Note that some manufacturers use this acronym (EICAS) to mean engine instrument caution advisory system.

b. Prominent Warning, Caution, and Advisory Issues

(1) Specific colors are required for warning and caution lights by 14 CFR §§ 23.1322, 25.1322, 27.1322, and 29.1322. However, it is not always clear when something should be classified a warning versus a caution. The same guidance and restrictions on the use of colors applies to displays as well, as is documented in the FAA displays ACs. AC 25-11 states that "a warning should be generated when immediate recognition and corrective or compensatory action is required; the associated color is red." For a caution, the same AC states that "a caution should be generated when immediate crew awareness and subsequent crew action is required and subsequent crew action will be required, the associated color is amber/yellow." The distinction between the two situations is subtle; however, the implications may be dramatic. Care must be taken when determining which situations constitute a warning and which should generate a caution.

(2) The dramatic increase in the number of systems on board aircraft has caused a corresponding increase in the number of Warning, Cautions, and Advisory (WCA). This has made it more difficult for pilots to determine which system generated the warning, caution or advisory. It must be readily apparent to the pilot which event or events generated the warning, caution or advisory. For example, 14 CFR § 25.1309(c) requires that, "Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards." Warning, Caution, and Advisory (WCA) messages should be clear, concise and easily interpreted.

(3) Due to size limitations and the need to display other flight essential information on multifunction display systems, not all WCA messages may be presented in the window concurrently. This results in a human factors/pilot interface issue because some status messages may be scrolled out of view or stored in message que. This is particularly problematic if warning messages are not in view. Some system designs have further exacerbated this problem by not enabling the pilot to recall all out of view messages.

(4) Human factors/pilot interface issues also occur when it is not obvious that new messages have been added. History and research is full of data documenting the failures of the human memory. A pilot cannot be expected to correctly remember every single previous warning, caution, advisory, or status messages, or even the number of previously displayed items. The FAA should also check for a frequently seen problem where avionics do indicate and differentiate newly added messages from existing messages. For example, some avionics may put all messages in a message que where it is impossible to tell which message was most recently added.

c. See appendix 1, issue 8: Warning, Cautions, & Alerts for requirements and guidelines.

d. Key References

(1) AC 25-11, "Transport Category Airplane Electronic Display Systems," dated July 16, 1987.

(2) AC 23.1311-1A, "Installation of Electronic Displays in Part 23 Airplanes," dated March 13, 1999.

(3) AC 27-1B, Certification of Normal Category Rotorcraft, AC Paragraph 1303, current revision.

(4) AC 29-2C, Certification of Transport Category Rotorcraft, AC Paragraph 1303, current revision.

15. PART II: ERROR PREVENTION, DETECTION & RECOVERY.

a. Background

(1) Human error has been cited as a contributing factor in over 70 percent of aircraft accidents. The level of attention this area has received is growing, partly because improved, more reliable and redundant mechanical systems have made design-induced flightcrew errors more conspicuous as a major contributor to aircraft accidents. Also, this is the one area that has the greatest potential to reduce aircraft accidents and incidents. Unfortunately, it is a difficult issue to understand and adequately address, particularly in complex aircraft.

(2) The possibility of error-free performance seems exceedingly remote. Human error is an abundant and ever-present part of life. There are a multitude of factors that contribute to human error, including design, training, previous experience, and operations. Although it may not be possible to eliminate human error, this does not mean that it should not continue to be a goal in aviation. There are a number of methods available to system designers to address this issue.

b. Prominent Error Prevention, Detection, and Recovery Issues

(1) The potential for pilot error should be considered in the design and evaluation of complex aviation systems. When reviewing the System Safety Assessment, it is important to ensure that appropriate flightcrew errors and the consequences of those areas are taken into consideration. Systems should be designed to (in order of priority):

(a) Eliminate or minimize the potential for pilot error;

(b) Limit the detrimental consequences of error; and

(c) Maximize error detection and recovery (for example, an "UNDO" key may help in error recovery).

(2) Typically a designer will adopt system design characteristics that use parts of all three mitigating methodologies. Regardless, special attention should be given to error recovery techniques by providing quick, easy, and consistent error recovery, as this is the last line of defense.

c. See appendix 1, issue 9: Error Prevention, Detection, and Recovery Issues for requirements and guidelines.

d. Key References

(1) DOT/FAA/RD-93/5, "Human Factors for Flight Deck Certification Personnel." Kim M. Cardosi & M. Stephen Huntley, dated July 1993.

(2) Reason, J., "Human Error," Cambridge, UK: Cambridge University Press, 1997.

16. CONCLUSION. This notice and appendices provide goals, criteria, and approaches to ensure a consistent, standard process for evaluating TSO human factors/pilot interface issues with complex, integrated avionics submitted for TSOA approval.

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Appendix 1
Part III: Summary of Human Factors Related Requirements & Recommendations

1. **INTRODUCTION.** These requirements and recommendations were extracted directly from TSOs, ACs, RTCA Minimum Operational Performance Standards (MOPS), and SAE Aerospace Recommended Practice (ARP) documents. The source is listed in parentheses immediately following each item. The full title of the source has been abbreviated to save space. Appendix 2 contains a complete reference list with the full title of each document.

a. Some requirements and recommendations have multiple references. In some cases, the wording in these source documents may be slightly different. The reviewer should refer to all of the referenced documents to address a particularly complex issue, or when guidance is ambiguous.

b. System specific words or acronyms were removed from requirement and recommendation statements. For example, the acronym for the electronic map display, "EMD," has been removed from the text in the requirements below. The acronym does appear in the original wording in the source document as well as in the reference so the reader knows the source for the requirement. This is to help the reviewer better understand the general issue and requirement, or recommendation, without being distracted when reading the requirements by system specific acronyms.

c. The words "shall," "must," or "should" appear in most of the requirements and recommendations. These words were retained from the original source documents. System specific guidance is only applicable, from a compliance perspective, to that particular system. Therefore, for those requirements using the word "shall," only that specific system, for which the requirement exists, must comply with that requirement.

d. The requirements and guidelines for specific avionics systems may also aid in identifying and resolving human factors related issues with other systems. Applicants may apply this guidance to other systems as appropriate.

e. The FAA should not require an applicant to meet requirements not associated with that system. For example, an applicant seeking TSO-C151a, Terrain Awareness and Warning System (TAWS), approval is not required to comply with any of the TSO-C146, Wide Area Augmentation System (WAAS), requirements. However, in this example the applicant seeking TSO-C151a may benefit from some of the general human factors guidance on computer interfaces, buttons, labels, etc., contained in the WAAS TSO. Thus, in some cases it may be suitable and useful to use the material in this appendix as recommended guidance, even though the original material was developed as requirements or guidance for another system.

f. Users of this notice should see the original source documents to review the context, assumptions, and further notes associated with the requirements that were extracted. This appendix should be used only as a quick reference for a subset of requirements and recommendations for human factors/pilot interface issues.

2. USE OF COLORS

a. Number of colors. No more than six colors should be used for color-coding on the display. See ARP4032 and appendix 6 for color guidelines. (Electronic Map Display (EMD) and Controller Pilot Data Link Communications (CPDLC) MOPS).

NOTE: Use of additional colors for other purposes should not detract from the discrimination of colors used for coding.

b. Use of red, amber, yellow, blue, and white. The use of all colors must be consistent with commonly accepted practice. The accepted practice for the use of red and amber is consistent with 14 CFR §§ 23.1322 and 25.1322 as follows: (WAAS, EMD, & CPDLC MOPS;DO-256 Section 2.1.3.6.)

(1) Red shall be used only for indicating a hazard that may require immediate corrective action.

(2) Amber shall be used for indicating the possible need for future corrective action.

(3) Any other color may be used for aspects not described in paragraphs 2a and b, providing the color differs sufficiently from the colors prescribed in these items to avoid possible confusion.

(4) Red should be used as the warning annunciation for emergency operational conditions when immediate flight crew recognition is required and immediate correction or compensatory action may be required. Amber should be used for the cautionary annunciation for abnormal operational conditions when immediate flight crew awareness is required and subsequent flight crew action may be required. White or another unique color should be used for advisory annunciations of operational conditions which require flight crew awareness and action may be required. Green should be used for indication of safe operating conditions. (AC 23.1311-1A.)

(5) Pure (e.g., "royal") blue should not be used for text, small symbols, other fine detail, or as a background color (See DOT/FAA/AR-99/52). (CPDLC MOPS; RTCA DO-256, Section 2.1.3.6.)

(6) Blue should be avoided because it is difficult for the human eye to bring blue symbols into focus and to distinguish the color from yellow when the symbols are small. (Ref. AC 25-11 for generally accepted aviation practices.) (WAAS MOPS.)

(7) Saturated red and blue should never be presented in close proximity to avoid a false perception of depth. (CPDLC MOPS; DO-256, Section 2.1.3.6.)

(8) Yellow and white are confusable and only one of them should be used to code text or small symbols. (CPDLC MOPS; DO-256, Section 2.1.3.6.)

c. Color consistency with common practice, paper charts, and other avionics.

(1) Prior to defining the color standard to be used in a specific display, establish a consistent color philosophy throughout the display. (AC 23.1311-1A.)

(2) Color-coding should be consistent across all system displays and controls. (CPDLC MOPS.)

d. Using color-coding redundantly

(1) Color-coded information should be accompanied by another distinguishing characteristic such as shape, location, or text. (EMD MOPS & WAAS MOPS.)

(2) Whenever color is used to code information, it shall be used redundantly with another means of coding information. (CPDLC MOPS; DO-256, Section 2.1.3.6.)

NOTE: This means that there should be some indication, other than color, about the information that the color is to convey. All information conveyed by color-coding should also be available under a monochrome presentation.

(3) Color is an enhancement for understanding the display information that leads to performance improvement, but it should not be the sole means of discrimination of critical information. (AC 23.1311-1A.)

e. Color discriminability. If color is used for information coding, the selected color set shall be absolutely discriminable (i.e., can be identified) under the full range of normally expected ambient light conditions. (WAAS MOPS & CPDLC; DO-256 Section 2.1.3.6.)

f. General.

(1) When colors are assigned a meaning, each color should have only one meaning. (CPDLC MOPS DO-256, Section 2.1.3.6.)

(2) Bright, highly saturated colors should be used sparingly and only be used for critical and temporary information so they are not visually distracting. (CPDLC MOPS DO-256, Section 2.1.3.6.)

(3) Color degradation should be obvious and should not preclude the pilot from interpreting the remaining display information. (AC 23.1311-1A.)

(4) Under high and low levels of lighting, color degradation should not prevent the pilot from properly interpreting display information. Where precipitation is integrated with other information, the precipitation colors can be presented at half intensity. Service experience has shown that this provides enhanced presentation and reduced ambiguity. Warnings should be at full intensity. (AC 23.1311-1A.)

(5) The following figure depicts colors found acceptable for compliance with § 23.1322, and other recommended colors as related to their functional meaning for electronic display systems: (AC 23.1311-1A.)

FIGURE 1. Display features should be color-coded as follows:
(AC 25-11, AC 23.1311-1A, and the Part 27 & 29 Mega AC)

Function	Color
Warnings	Red
Flight envelope and system limits	Red
Cautions, abnormal sources	Amber/Yellow*
Earth	Tan/Brown
Scales and associated figures	White
Engaged modes	Green
Sky	Cyan/Blue
ILS deviation pointer	Magenta
Flight director bar	Magenta/Green

*The extensive use of the color yellow for other than caution/abnormal information is discouraged.

3. SYMBOLOGY

a. Symbol discriminability and distinctiveness

(1) Symbols shall be distinctive and discriminable from one another. (From WAAS MOPS)

(2) Symbols should be distinctive to minimize misinterpretation or confusion with other symbols utilized in the displays. Symbols representing the same functions on more than one display should utilize the same shape and/or color-coding. (AC 23.1311-1A)

(3) The system shall display distinctive symbols for different fix types (waypoints, airports, VORs, NDBs, intersections) and the aircraft (ownship). (EMD MOPS.)

NOTE: If the input to the system does not distinguish between flight plan fix types (e.g. VOR vs. NDB), then the waypoint symbol is acceptable. However, if off-route fixes (e.g. VORs) are displayed, they must use the distinctive symbols appropriate for the fix type. (EMD MOPS.)

(4) Required symbols shall be discriminable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions. (EMD MOPS.)

(5) Symbols shall be discriminable at a nominal viewing distance of 29 inches, a minimum

viewing distance of 10 inches and a maximum viewing distance of 40 inches under all flight deck lighting conditions (SAE AIR 1093). (CPDLC MOPS; RTCA DO-256, Section 2.1.3.1.)

b. Symbol consistency with paper charts, other avionics, and aviation industry standards

(1) The system shall use symbols similar to those shown on published charts or that are consistent with established industry standards. Guidelines for electronic display symbology are provided in SAE ARP5289. (EMD Appendix H & WAAS MOPS.)

(2) Symbols for graphic presentation should be consistent within the flight deck. (CPDLC MOPS; RTCA DO-256, Section 2.1.3.1.)

c. Symbols to be used for only one purpose.

(1) Symbols used for one purpose on published charts should not be used for another purpose on the equipment display. (WAAS & EMD MOPS.)

(2) Symbols used for one purpose in one flight deck system should not be used for another purpose with another system. (CPDLC MOPS.)

(3) Symbols shall be used for a single purpose within the system. (CPDLC; RTCA DO-256, Section 2.1.3.1.)

d. Symbol orientation

(1) All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. (EMD MOPS.)

(2) A symbol indicating a particular compass orientation shall maintain that compass orientation at all times. An example of this is a depiction of a runway symbol that maintains proper compass orientation as the map rotates. (EMD MOPS in Figure 2-2.).

(3) The aircraft/ownship symbol shall be directional, oriented to either heading or track. (EMD MOPS.)

(4) If the EMD supports more than one aircraft symbol directional orientation (e.g., heading and track), then the current aircraft symbol orientation shall be indicated. (EMD MOPS.)

4. LABELS

a. General

(1) The equipment shall provide a minimum 5-character field for input and display of database fix identifiers. (WAAS MOPS paragraph 2.2.1.2.1.)

(2) Airport identifiers shall be accessible using standard ICAO nomenclature when available (e.g., KJFK) (WAAS MOPS paragraph 2.2.1.2.1.)

(3) Waypoint names shall be consistent with published names. (WAAS MOPS, Section 2.2.1.2.1.)

(4) The equipment shall provide a means for the operator to differentiate between duplicate waypoint identifiers in the database, including waypoints in the navigation database and user defined waypoints. (WAAS MOPS, Section 2.2.1.2.1.)

(5) Data fields shall include the units of measurement or labels for the displayed data (Smith & Mosier, 1986). (CPDLC MOPS.)

(6) Numeric message fields shall include a display of labels or units of measure for altitude, heading, and speed. (CPDLC MOPS; RTCA DO-256, Section 2.1.3.5.)

(7) Labels shall be used to identify the functions of all system controls. (EMD & CPDLC MOPS; RTCA DO-256, Section 2.1.3.5.)

(8) Labels shall be used to identify fixes, other symbols, and other information, depicted on the EMD, where appropriate. (EMD MOPS.)

(9) Labels for controls should be on or adjacent to controls they identify. (CPDLC MOPS.)

(10) The spatial relationships between labels and the objects that they reference should be clear, logical, and consistent. (EMD & CPDLC MOPS; RTCA DO-256, Section 2.1.3.5.)

(11) Label placement should follow a consistent logic. (WAAS MOPS.)

(12) Data field labels shall be located sufficiently close to, but separated by at least one space from, the associated with the data field (Smith & Mosier, 1986). (CPDLC MOPS; RTCA DO-256, Section 2.1.3.5.)

(13) Soft control labels (e.g., response options) should be displayed in a consistent location on all CPDLC screens. (CPDLC MOPS.)

(14) Soft control labels shall be unambiguously associated with the control they label (e.g., either through location or through an indicator of which control is associated with the label). (CPDLC MOPS; RTCA DO-256, Section 2.1.3.5.)

(15) Labels should be unobstructed by controls when viewed within the angle of regard, and located next to or on the controls that they reference. (WAAS MOPS.)

(16) Labels shall be readable from viewing distances of 30 inches, under anticipated lighting conditions. (Section 2.5.10.2.2.)

(17) All labels shall be readable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions (MIL STD 1472D, SAE AIR1093). (EMD MOPS.)

NOTE: The size of numbers and letters required to achieve acceptable readability may depend on the display technology used.

(18) All labels shall be readable at a viewing distance of 29 inches under all anticipated lighting conditions (SAE/AIR 1093). (CPDLC MOPS.)

(19) All labels shall be readable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions (MIL STD 1472D, SAE AIR1093). (EMD MOPS.)

NOTE: The size of numbers and letters required to achieve acceptable readability may depend on the display technology used.

(20) CPDLC shall use an alphanumeric font of a sufficient thickness and size to be readable when users are seated at the normal viewing distance from the screen. Sans serif fonts are recommended. At a minimum, character height should be 1/200 of viewing distance (e.g., a viewing distance of 36 inches requires a .18 inch character height on the screen) (DOD-CM-400-18-05, p 12-1). (CPDLC MOPS RTCA DO-256 Section 2.1.3.5.)

NOTE: The size of numbers and letters required to achieve acceptable readability may depend on the display technology used. Stroke width between 10 and 15 percent of character height appears to be best for word recognition on text displays and extensions of descending letters (p,q) and ascending letters (b, d) should be about 40% of letter height. This information is available in: Bouma (1971), Vision Research, 11, 459-474; Bouma (1979), In Handbook of Psychonomic, Vol 1 Chapter 8, pp 427-531; Van Ness and Bouma (1980), Human Factors,463-475.

(21) Fix labels shall be oriented to facilitate readability. (EMD MOPS; RTCA DO-257.)

NOTE: One method of compliance is to continuously maintain an upright orientation.

b. Font

(1) A simple font should be used for all alphanumerics. (WAAS MOPS.)

(2) Alphanumeric fonts should be simple and without extraneous details (e.g., sans serif) to facilitate readability. (EMD MOPS.)

c. Bearing Labels. All bearings shall be labeled as "°" to the right of the bearing value. All true bearings shall be labeled as "°T" to the right of the bearing value. The "°T" label could be indicated with a single or two characters. (This applies to all courses, tracks, and bearings).

(WAAS MOPS.)

NOTE: The "°T" label could be indicated with a single or two characters. (This applies to all courses, tracks, and bearings). Reference RTCA DO-229A requirements for text.

d. Nomenclature. Label terminology and abbreviations used for describing control functions and identifying system controls should be consistent with appendices 1 and 2. (EMD MOPS.)

e. Set of Standard Function Labels (WAAS MOPS).

(1) When using abbreviations and acronyms, the abbreviations and acronyms provided in the WAAS MOPs shall be used for checklists, messages, and labels for control functions. These abbreviations should not be used to represent a different term. These standards shall be used consistently in the design of the pilot handbook supplements, quick reference checklists and the controls and displays of the equipment. (WAAS MOPS.)

NOTE 1: These requirements are intended to increase the compatibility and consistency between different GPS/WAAS equipment. This will become more important as GPS/WAAS equipment begins to replace VOR and DME equipment as the basic navigation capability.

NOTE 2: See also appendix 7 in this notice, SAE G10 acronym list, and AIM acronym list & definitions.

(2) Figure 2a provides a list of functions and indicates labels and messages that should be used for each one. Not all of these functions may be required. If a function is implemented as a discrete action, the equipment shall use the labels or messages as provided in the figure. If several of the following functions are accomplished as a discrete action, one of the applicable labels in figure 2a shall be used (e.g., suspend automatic sequencing and accessing the ability to select a course to or from a waypoint would be labeled "DCRS"). Except for waypoint identifiers, these abbreviations shall not be used to represent a different term.

FIGURE 2a. Function Labels and Messages

Function	Label/Message
Enter, confirm or acknowledge	Enter (ENT)
Suspend / unsuspend automatic waypoint sequencing	Suspend (SUSP)
Access to selecting a course to or from a waypoint	OBS, CRS[1]
Clear previous entry, no, or delete	Clear (CLR)
Activates and deactivates the cursor	Cursor (CRSR)
Access to a message	Message (MSG)
Access Direct-To function	Direct To (-D→)
Access to nearest airports or other fixes	Nearest (NRST)
Access to flight planning functions	Flight Plan (FPL)
Select Vectors-to-Final (Section 2.2.3.2.1)	Vectors-to-Final (VTF)
Access to primary navigation display (Section 2.2.1.4.1)	NAV

[1] If this function is accomplished using a button, it shall be labeled "OBS" to avoid confusion with "CRSR". For display of the selected course, including the ability to select that course, it may be labeled "OBS" or "CRS".

(3) Figure 2b provides a list of common annunciations and the associated labels and messages that should be used.

FIGURE 2b. Annunciation Labels and Messages

Annunciations	Label/Message
Indication that there is a message	Message (MSG, M reverse-video M)
Indication of loss of integrity monitoring	LOI "Loss of Integrity - Cross Check Nav."
Indication of impending turn	WPT (flashing)[1], or "Turn to [next heading] in [distance] nm"
Indication of start of turn	WPT (continuously lit, not flashing)[1], or "Turn to [next heading] now"

[1] This can be used to indicate other conditions (e.g., waypoint alerting).

5. SYSTEM STATUS INDICATIONS, MODES, ANNUNCIATIONS, & MESSAGES.

a. General

(1) Current map orientation shall be clearly, continuously, and unambiguously indicated (i.e. track-up vs. North-up).

NOTE: Issue: systems exist that have four orientation modes available without any explicit indication of mode: actual track-up, north-up, heading-up, desired track-up. The orientation mode selected must be continuously indicated. Alternatively, the indication could be done using external annunciators or an external switch that indicates the orientation currently selected.

An acceptable means of compliance would be to have a "desired track-up" (or DTK↑), "north-up" (or N ↑), "heading-up" (or HDG ↑) or "actual track-up" (or TRK ↑) on the display.

A compass rose or North indicator is an acceptable means of compliance for a system that provides only two options (North-up and one other option).

(2) If the system has the ability to operate in different modes, that system shall continuously indicate what operating mode the system is in. (CPDLC MOPS; RTCA DO-256, Section 2.1.5.)

(3) The system logon interface shall indicate the type and format of input data expected.

(4) The system shall indicate functions or responses that are available. For example, applicable response options may be indicated when the pilot selects a specific message.

(5) If information from more than one navigation source can be displayed, the selected source should be continuously indicated to the pilot. If multiple sources can be displayed simultaneously, the display should indicate unambiguously what information is provided by each source and which is for guidance. Distinctive scales or points should differentiate between angular deviations (e.g., ILS, VOR) and linear deviations (e.g., GPS, FMS). (AC 23.1311-1A.)

(6) The electronic display system should provide the pilot with visibly discernible annunciators that will indicate to the pilot the system operating modes. The visual annunciators should be distinctive under all normal lighting conditions and consistent with cockpit warnings. Under night lighting with the display average brightness at the lowest usable level for prolonged flight, visual annunciators should be usable. Annunciations should be consistently located in a specific area of the electronic display, to ensure proper interpretation by the pilot. Except for a flight director display, use of the display selection control position as annunciation is acceptable only when the control position is in direct view of the pilot, without head movement, and when the control position is obvious under all lighting conditions. When a failure occurs or when reversionary modes are used, an annunciation of abnormal system status shall be provided per 14 CFR § 23.1311(a)(7). The display should not provide hazardously misleading information. (AC 23.1311-1A.)

(7) When multiple system configurations and more than one sensor input are available for source selection, the switching configuration by annunciation or by selector switch position should be readily visible, readable, and should not be hazardously misleading to the pilot using the system (AC 23.1311-1A).

b. Orientation & Range Indications

(1) The system shall have the capability to present map information in 1) a North-up orientation and 2) at least one of the following orientations: actual track-up, heading-up, or desired track-up. (EMD MOPS; RTCA DO-257.)

(2) If the system has the ability to change between true and magnetic north, the system shall indicate the current selection.

NOTE: This may be done using a mode indicator.

(3) The system shall have the capability of changing the map range. (EMD MOPS; RTCA DO-257.)

(4) Current map range shall be indicated continuously. (EMD MOPS; RTCA DO-257.)

(5) If the system is controlling the map range automatically, the mode (e.g., auto map range) should be indicated. (EMD MOPS; RTCA DO-257.)

c. Messages

(1) Messages should be grouped by urgency level and listed chronologically within each group.

(2) All current messages shall be retrievable.

(3) An indication shall be provided to identify new messages.

(4) The equipment should also indicate when there are current messages. (WAAS MOPS.)

d. Message Display & Formatting

(1) Consistent formats should be used to present messages on all displays.

(2) Standard locations and formats for data should be used to facilitate data entry and error checking and reduce the time and errors associated with reading the data. (RTCA DO-256, Section 2.1.7.2.)

(3) If the complete message cannot be presented on the same page, there shall be a clear indicator to the pilot that the message continues.

(4) Lines of text shall be broken only at spaces or other natural delimiters.

(5) Conditions and restrictions associated with parameters and text shall be adjacent to and grouped with their descriptive or explanatory text or labels.

(6) Message data shall be available in a directly usable form. If altitude is required in meters or feet, then both values should be available without requiring the pilot to convert displayed data.

e. Message Composition & Response

(1) If messages require data entry, the system shall provide a preview of all messages as they are composed, and before they are sent by the pilot.

(2) The system shall support editing of pilot-composed messages

(3) For messages that require a pilot response, the system shall indicate the set of appropriate response options (RTCA DO-256).

6. <u>CONTROLS</u>.

a. General

(1) Controls should be designed to maximize usability, minimize flight crew workload, and reduce pilot errors. Operations that occur with high frequency or in the terminal area should be executable with a minimum number of control operations. (EMD MOPS.)

(2) The use of controls should not cause inadvertent activation of adjacent controls. (EMD MOPS.)

NOTE: Common and acceptable means of reducing the likelihood of inadvertent operation through key design include the following: (EMD MOPS; See also similar item from WAAS MOPS.)

- A minimum edge-to-edge spacing between buttons of 1/4 inch. (Keys should not be spaced so that sequential use is awkward or error prone.)
- Placing fences between closely spaced adjacent controls.
- Concave upper surface of keys to reduce slippage.
- Size of control surface sufficient to provide for accurate selection.

(3) Controls should be designed to facilitate nighttime usability (i.e., illuminated).

NOTE: Control illumination may be achieved by either illuminating the control itself or providing flight deck (external) illumination. This will need to be evaluated on an installation specific basis.

b. Layout

(1) To the extent possible, controls should be organized according to the following

principles: (CPDLC HF MOPS.)

(a) Collocate the controls with associated displays.

(b) Partition the controls into functional groups.

(c) Place the most frequently used controls in the most accessible locations.

(d) Arrange the controls according to the sequence of use.

(2) Controls that are normally adjusted in flight shall be readily accessible to the flight crew (FAR 25.777c). (CPDLC HF MOPS.)

(3) Controls that do not require adjustment during flight should not be readily accessible to the flight crew. (CPDLC HF MOPS)

(4) CPDLC controls should be arranged so that they do not obscure other controls or displays. (CPDLC HF MOPS) (See also similar item below.)

(5) Controls that are normally adjusted in flight shall be accessible without interfering with the visibility of critical displays. (WAAS MOPS.)

c. Operation of Controls

(1) Controls shall provide feedback when operated. Tactile and visual cues are acceptable forms of feedback. (EMD, WAAS , & CPDLC MOPS; RTCA DO-256, Section 2.1.2.2.)

(2) The system should respond to operator control inputs within 250 msec.

NOTE: If the system response time to an operator control input exceeds 250 msec, a temporary visual cue should be provided to indicate that the control operation has been accepted by the system (e.g., hour glass or message).

(3) Controls shall be resistant to inadvertent activation. (EMD and CPDLC MOPS.)

NOTE: This may be achieved by employing adequate control size, height, resistance, displacement, and spacing or guards between controls.

(4) Controls designed to be used in flight shall be operable with one hand. (EMD & CPDLC, WAAS MOPS.)

(5) Activation or use of a control should not require simultaneous use of two or more controls in flight (e.g. pushing two buttons at once). (EMD & CPDLC MOPS RTCA DO-256 Section 2.1.2.2.)

(6) Operations that occur frequently should be executable with a minimum number of actions. (CPDLC HF MOPS.)

(7) Dedicated controls should be used for frequently used functions. (CPDLC HF MOPS)

(8) If a control can be used for multiple functions, the current function shall be indicated and discriminable in all environmental conditions (e.g., lighting, ambient noise, turbulence). (EMD, WAAS, & CPDLC MOPS.)

(9) There should be a clear indication when any control is in an altered state and not the default (e.g., if a knob is pulled out and functions differently). (WAAS MOPS.)

(10) The data link system shall echo pilot alphanumeric inputs within 0.2 s and respond to pilot inputs within 0.5 s, either by completing the processing or by providing feedback that the input is being processed, to prevent slowing tasks down and inducing entry errors such as multiple entries (Smith and Mosier, 1986). (CPDLC HF MOPS.)

(11) The controls should be easily identified and located in all lighting conditions, allow differentiation of one control from another, and have feedback through the system appropriate for the function being controlled. (AC 23.1311-1A.)

7. DISPLAY PLACEMENT & READABILITY.

a. Viewing angle/Angle of Regard

(1) All displays shall be fully readable up to a horizontal viewing angle of 35 degrees from normal to the face of the display screen. (WAAS MOPS, paragraph 2.2.1.1.4.3.)

(2) They shall be fully readable up to a vertical viewing angle of 20 degrees from normal to the face of the display screen. (WAAS MOPS, paragraph 2.2.1.1.4.3.)

(3) This angle of regard does not ensure that the equipment may be installed in any aircraft; it is recommended that the angle of regard be maximized to increase the flexibility of the equipment for installation. (WAAS MOPS, paragraph 2.2.1.1.4.3.)

b. Installation in the primary and normal fields of view for GPS panel mount units (TSO-C129, Class A. AC 20-138 (para 8(b)3) states that each display element used for primary navigation display should be in the pilot's primary field of view (e.g., within 15 degrees of the pilot's primary line of sight). The horizontal (and vertical) deviation display(s) and failure annunciation should be located within the pilot's primary field of view (i.e., within 15 degrees of the pilot's primary line of sight), as should any indication requiring immediate aircrew action. Other annunciations should be installed in the normal field of view (e.g., a location in the center radio stack or other location on the pilot's panel within the field of view at a height suitable for normal viewing from the pilot's seated position). This includes loss of integrity monitoring (RAIM), waypoint sequencing, start of a turn, turn anticipation, TO/FROM indication, approach mode annunciation and automatic mode switching. Note that for maneuver anticipation, this is a relaxation of the policy defined in AC 20-138. (FAA Memorandum titled "Information: Q & A from Seattle Avionics Workshop- (Navigation Related)" dated July 12, 1999.)

c. Display Placement & Readability

(1) Each flight, navigation, and powerplant instrument for use by any pilot must be plainly visible to him from his station with the minimum practical deviation from his normal position and line of vision when he is looking forward along the flight path. (FAR Part 25.1321.)

(2) Controls and displays should be clearly visible and usable by the pilot, with the least practical deviation from the normal position and from the line of vision when the pilot is looking forward along the flight path. (AC 23-1311-1A.)

(3) Angle of Regard: All displays shall be fully readable up to a horizontal viewing angle of 35 degrees from normal to the face of the screen. They shall be fully readable up to a vertical viewing angle of 20 degrees from the normal to the face of the display screen. This angle of regard does not ensure that the equipment may be installed in any aircraft; it is recommended that the angle of regard be maximized to increase the flexibility of the equipment installation. (WAAS MOPS.)

(4) Useful Screen: Equipment shall provide the maximum size active viewing area consistent with the limitations of unit outline and required features (controls, handles, etc.) (ARP 1874.)

(5) Viewing Characteristics: All indicating means (indicia, pointers, symbols, etc.) on the useful display surface shall be completely visible from any design eye position within the instrument's viewing envelope as specified by the manufacturer. Each installation should be examined to insure that the design eye position is within the instrument's viewing envelope. The examination may be a combination of test, analysis, simulation or flight test. (ARP 1874.)

(6) Cross-cockpit viewing to the other pilot's displays should be provided to achieve the capability dictated by certain failure conditions of critical functions. The off-axis angle is installation dependent and may exceed 50 degrees from a normal to the display. Displays mounted on a center pedestal should be visible to both pilots. (ARP 1874)

8. WARNING, CAUTIONS, & ALERTS.

a. Warning, Cautions, & Alerts

(1) Warnings, annunciations, and messages not critical to the safety of instrument approaches or missed approaches should be suppressed during those phases of terminal operations. (Editors note: from either WAAS MOPS or AC 23.1311-1A.)

(2) Alerting messages should differentiate between normal and abnormal indications. Abnormal indications should be clear and unmistakable, using techniques such as different shapes, sizes, colors, flashing, boxing, outlining, etc. Individual alerts should be provided for each function essential for safe operation. (AC 23.1311-1A.)

(3) A complete list of warnings, cautions, and annunciation messages should be included in the AFM, supplemental AFM, and placards. If the manufacturer's Pilot Operating Guide is found adequate and acceptable, it may be referenced in the AFM or supplemental AFM as a means to satisfy this requirement. (AC 23.1311-1A.)

(4) Alerts and alarms shall be distinctive and discriminable from one another. (WAAS MOPS.)

(5) For warnings and cautions, 14 CFR §§ 23.1322, 25.1322, 27.1322, and 29.1322 provide specific requirements for the assignment of red and amber for visual annunciations. (AC 23.1311-1A.)

b. Navigation Alerts (WAAS MOPS).

(1) Class Beta equipment shall provide an indication or output of the loss of navigation capability within one second of the onset of any of the following conditions:

(a) The absence of power (loss of function is an acceptable indicator);

(b) Probable equipment malfunction or failure (must consider all malfunctions and failures that could affect the navigation function and are more probable than 10^{-5});

(c) The presence of a condition lasting five seconds or more where there are an inadequate number of usable satellites to compute a position solution (i.e., no computed data);

(d) The presence of a condition where fault detection detects a position failure, which cannot be excluded within the time-to-alert.

(2) The equipment shall distinguish between these different causes of the loss of navigation capability. For example, a single navigation alert can be provided if it is accompanied by a message indicating the cause of the alert.

(3) The alert shall be returned to its normal state immediately upon termination of the responsible condition.

NOTE: These requirements do not preclude the implementation of a dead reckoning mode, which would allow continued display of navigation information even under condition (c), together with a clear indication that the equipment is using the dead reckoning mode.

(4) The alert shall be returned to its normal state immediately upon termination of the responsible condition.

NOTE: A navigation alert does not require removal of navigation information from the navigation display. Consideration should be given to continued display of navigation information concurrent with the failure/status annunciation when conditions warrant.

9. ERROR PREVENTION, DETECTION AND RECOVERY.

a. The system should be designed to detect and trap errors (for example, out-of-range values, and invalid alphanumerics) as the inputs are entered.

b. Out-of-range or invalid flight crew entries shall prompt an error message from the system to assist the pilot in determining the nature of the error and how to correct it.

c. Adequate precautions should be taken in the design process and adequate procedures should be specified in the maintenance manual to prevent the incorrect installation, connection or adjustment of parts of the automatic pilot if such errors would hazard the aeroplane (e.g., torque clutches or limit switches with a range of adjustment such that maladjustment could be hazardous) (Current ACJ 25.1329).

d. The controls, indicators and warnings should be designed as to minimize crew errors (Current ACJ 25.1329).

APPENDIX 2. REFERENCES

See also appendix 3 for a partial list of Technical Standard Orders considered "complex, integrated avionics."

1. FAA PUBLICATIONS

a. FAA Policy Memo ANM-99-2 "Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks."

b. FAA Notice 8110.80, "The FAA and Industry Guide to Product Certification."

c. FAA Order 8150.1A, "Technical Standard Order Program," September 21, 1987.

d. FAA Order 8110.4B, "Type Certification," April 24, 2000.

e. FAA Order 4040.26A, "Aircraft Certification Service Flight Safety Program, dated March 23, 2001.

f. AC 21-40, "Application Guide for Obtaining a Supplemental Type Certificate," May 6, 1998.

g. AC 23-8A, "Flight Test Guide for Certification of Part 23 Airplanes," February 9, 1989.

h. AC 25-7A, Change 1, "Flight Test Guide for Certification of Transport Category Airplanes," March 31, 1998.

i. AC 27-1B, "Certification of Normal Category Rotorcraft," latest revision.

j. AC 29-2C, "Certification of Transport Category Rotorcraft," latest revision.

k. Williams, James H., "Description of the FAA Avionics Certification Process," FAA Document, April 23, 1997. Note: This document is available on the Internet at http://www.faa.gov/avr/air/air100/100home.htm.

k. FAA Booklet, "The FAA Type Certification Process," Aircraft Certification Service, May 1996.

l. GAMA/Aerospace Industries Association/Aviation Electronics Association/FAA, "The FAA and Industry Guide to Avionics Approvals," April 2001.

m. FAA Order 8400.10, Chapter 15. "Manuals, Procedures, and Checklist," (Section 1. Background and Definitions).

n. FAA Memorandum titled "Information: Q & A from Seattle avionics Workshop (Navigation Related)," dated July 12, 1999.

o. 14 CFR §§ 23.1322, 25.1322, 27.1322, and 29.1322, "Warning, Caution, and Advisory Lights."

p. 14 CFR. § 25.777c, Cockpit controls. (See also 14 CFR §§ 23.777, 27.777, and 29.777).

q. FAA TSO C129a, "Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)," dated February 20, 1996.

r. FAA TSO C113, "Airborne Multipurpose Electronic Displays," dated October 27, 1986.

s. FAA TSO C151a, "Terrain Awareness and Warning System (TAWS)," dated November 29, 1999.

t. FAA TSO C146, "Stand-Alone Airborne Navigation Equipment using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)," dated October 6, 1999.

u. FAA TSO C147, "Traffic Advisory System (TAS) Airborne Equipment," dated April 6, 1998.

v. AC 25-11, "Transport Category Airplane Electronic Display Systems," dated July 16, 1987.

w. AC 23.1311-1A, "Installation of Electronic Displays in Part 23 Airplanes," dated March 13, 1999.

x. USDOT-FAA/Civil Areomedical Institute: Aeromedical Certification Division Aeromedical Certification Statistical Handbook, 1998.

y. DOT/FAA/CT-96/1, "Human Factors Design Guide for Acquisition of Commercial Off-The-Shelf Non-Developmental Systems and Developmental Systems."

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APPENDIX 3. PARTIAL INDEX OF COMPLEX, INTEGRATED TSOs

The following is a partial list of the FAA Technical Standard Orders (TSOs) considered complex, integrated avionics. Note that applicants may apply for a TSO that does not adequately address all of the functionality in the system. Alternatively, applicants may apply for multiple TSOs, since no single TSO applies to all functions. If the applicant applies for multiple TSOs for a single system, that combination of TSOs may result in the system being considered complex or integrated, even though the individual TSOs were not.

PARTIAL INDEX OF COMPLEX, INTEGRATED TSOs IN NUMERICAL SEQUENCE

TSO NUMBER		SUBJECT TITLE
TSO-C2d	6/14/89	Airspeed Instruments
TSO-C10b	9/1/59	Altimeter, Pressure Actuated, Sensitive Type
TSO-C52b	5/30/95	Flight Director Equipment
TSO-C63c	8/18/83	Airborne Weather and Ground Mapping Pulsed Radars
TSO-C67	11/15/60	Airborne Radar Altimeter Equipment (For Air Carrier Aircraft)
TSO-C92c	3/19/96	Airborne Ground Proximity Warning Equipment
TSO-C93		Airborne Interim Standard Microwave Landing System Converter Equipment
TSO-C94a	8/12/81	Omega Receiving Equipment Operating within the Radio Frequency Range of 10.2 to 13.6 Kilohertz
TSO-C101	2/19/87	Over Speed Warning Instruments
TSO-C102	4/2/84	Airborne Radar Approach and Beacon Systems for Helicopters
TSO-C104	6/22/82	Microwave Landing System (MLS) Airborne Receiving Equipment
TSO-C105	6/13/84	Optional Display Equipment for Weather and Ground Mapping Radar Indicators
TSO-C106	1/15/88	Air Data Computer
TSO-C110a	10/26/88	Airborne Passive Thunderstorm Detection Equipment
TSO-C113	10/27/86	Airborne Multipurpose Electronic Displays
TSO-C115b	9/30/94	Airborne Area Navigation Equipment Using Multi-Sensor Inputs
TSO-C117a	8/1/96	Airborne Windshear Warning and Escape Guidance Systems for Transport Airplanes
TSO-C118	8/5/88	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS I
TSO-C119a	4/9/90	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II
TSO-C120	1/26/88	Airborne Area Navigation Equipment Using Omega/VLF Inputs
TSO-C129a	2/20/96	Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)
TSO-C146	10/6/99	Stand-Alone Airborne Navigation Equipment Using The Global Positioning System (GPS) Augmented By The Wide Area Augmentation System (WAAS)
TSO-C147	4/6/98	Traffic Advisory System (TAS) Airborne Equipment
TSO-C151a	11/29/99	Terrain Awareness and Warning System

APPENDIX 4. SUGGESTED METHOD OF COMMUNICATING CERTIFICATION ISSUES, CONCERNS AND COMMENTS

There are currently two common methods used to document and communicate issues between the FAA and applicants.

1. In the first, the applicant records FAA issues/comments made during the meeting in the meeting minutes. The applicant then sends the minutes to the FAA for concurrence. The FAA should review the minutes and make changes as needed for accuracy and completeness. The resulting edited list is then returned to the applicant for their action.

2. In the second method, the FAA records and documents their own issues/comments and provides them to the applicant. The applicant is responsible for reviewing and responding to those issues requiring resolution before the TSO is granted.

3. Regardless of the method chosen, it is extremely important that issues are documented, clear, accurate, and understood by both the applicant and the FAA. Also, the applicant must be given the reason something is an issue and what action, if any, the FAA expects the applicant to take. To aid this communication process, a suggested form and content is presented in figure 1.

Figure 1. EXAMPLE OF AN ISSUES LIST

Item No.	Date ID'd	Input Cat.	Issue Description	FAR Ref.	Applicant Position	Status
1	02/10/01	Issue	The applicant has proposed to use a red indicator light to indicate that pitot heat has been selected. Use of red indicator lights is restricted for those situations that present a hazard that may require immediate corrective action. The FAA requests that the applicant provide substantiation that the selection of pitot heat is a hazardous situation that may require immediate corrective action.	25.1322(a)	A response is being prepared.	Open

4. FAA issues may be documented and presented in a number of different ways. The FAA and applicant should agree to a format and record-keeping system at the beginning of the program. Regardless of the approach used, it must be obvious which are clearly certification issues. This should be stated in the documentation. In some cases, the FAA may not be able to determine whether a design or operation characteristic is an issue or not. It is appropriate and desirable for the FAA to communicate these "concerns" to the applicant early in the program as they are

discovered. This will allow the FAA and applicant to stay aware of the item and ensure that it is adequately addressed in the project.

5. We recommended that documented issues include at least the following information:

a. Description of the current configuration,

b. Statement concerning the non-compliance or potential non-compliance issue with that configuration,

c. Pertinent regulatory references and guidance, and

d. Statement of expected applicant action, if any.

6. For example, suppose an applicant has proposed to use a red indicator light to indicate that pitot heat has been selected. Item 1 in figure 1 shows how this might be presented.

7. In the issue description column of figure 1 it is important to document how you understand that the function or aspect under review works and what version or configuration control was reviewed. This is especially important, for the system may have changed since that review. Additionally, the applicant needs to know specifically what the problem is and why it is a problem. The "why it is a problem" is typically addressed by reference to the applicable 14 CFR, Part requirement. Lastly, the applicant needs to know what action the FAA expects them to take. In some cases, the FAA may just require additional data or information. Regardless, the expected applicant response should be stated in the documentation.

APPENDIX 5. PRIORITIZATION TABLE FROM THE TAWS TSO

FIGURE 1. Prioritization Scheme for Voice Aural Alerts

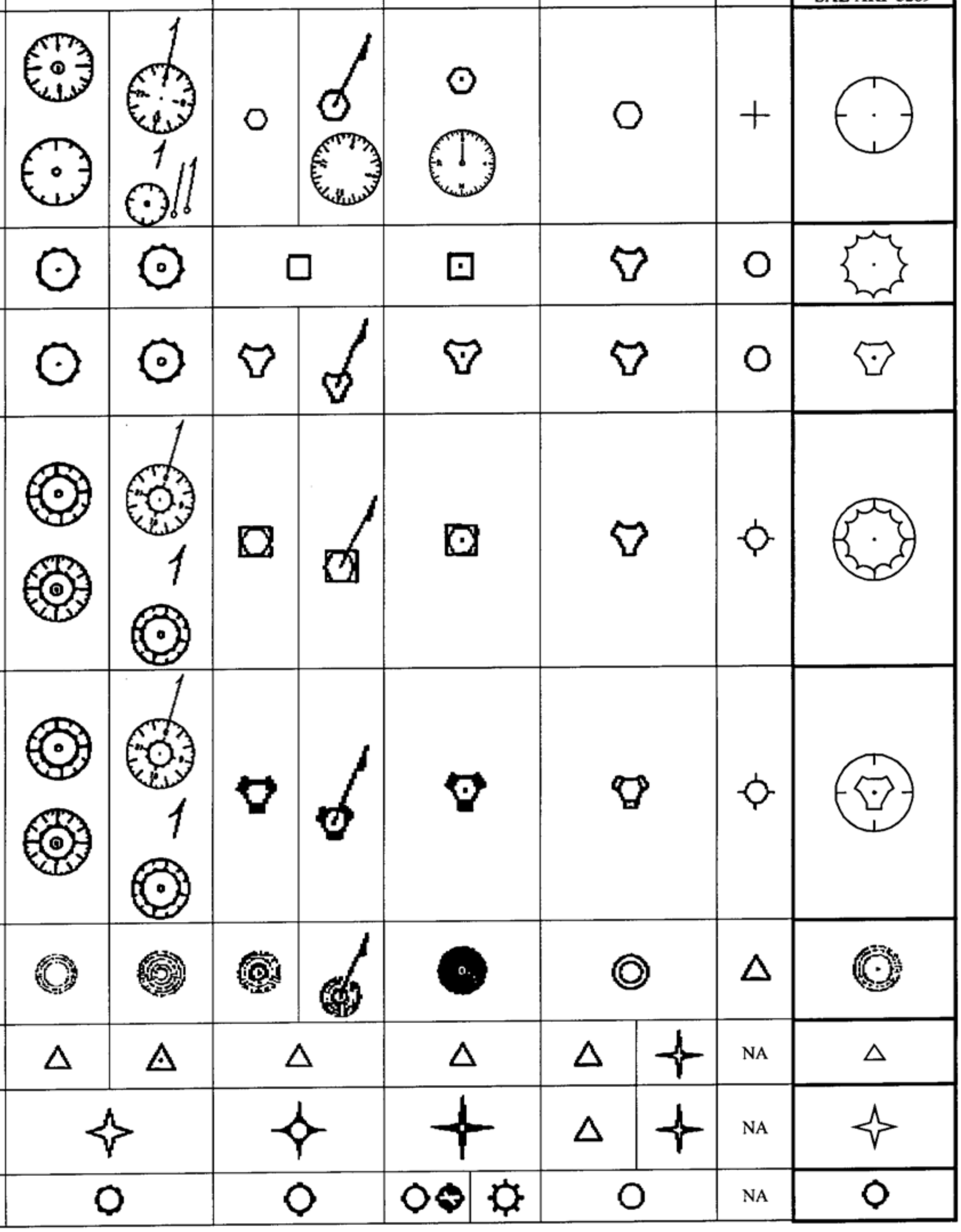
Priority	Initiating System	Description	Alert Level [d]	Comments [a]
1	GPWS	Reactive Windshear Warning (Mode 7)	W	
2	GPWS	Sink Rate Pull-Up Warning (Mode 1)	W	continuous
3	GPWS	Terrain Closure Pull-Up Warning (Mode 2)	W	continuous
4	GPWS	Terrain Warning (Mode 2A preface)	W	
5	GPWS	V_1 Callout [b]	I	
6	GPWS	Engine Fail Callout [b]	W	
7	**EGPWS**	**Terrain Awareness Pull-Up warning**	W	continuous
8	**PWS**	**PWS Warning**	W	
9	GPWS	Terrain Caution (Mode 2)	C	continuous
10	GPWS	Minimums (Mode 6)	I	
11	**EGPWS**	**Terrain Awareness Caution**	C	7 s period
12	GPWS	Too Low Terrain (Mode 4)	C	
13	**EGPWS**	**TCF ("Too Low Terrain") Caution**	C	
14	GPWS	Altitude Callouts (Mode 6)	I	
15	GPWS	Too Low Gear (Mode 4)	C	
16	GPWS	Too Low Flaps (Mode 4)	C	
17	GPWS	Sink Rate (Mode 1)	C	
18	GPWS	Don't Sink (Mode 3)	C	
19	GPWS	Glideslope (Mode 5)	C	3 s period
20	**PWS**	**PWS Caution**	C	
21	GPWS	Approaching Minimums (Mode 6)	I	
22	GPWS	Bank Angle (Mode 6)	C	
Mode 6 [c]	TCAS	TCAS RA ("Climb", "Descend", etc.)	W	continuous
Mode 6 [c]	TCAS	TCAS TA ("Traffic, Traffic")	C	continuous

NOTE: New alerts shown in gray
[a] With interleaving (a.k.a. audio de-clutter)
[b] Boeing 777 only.
[c] These alerts can occur simultaneously with GPWS Mode 6 alerts.
[d] W = Warning, C = Caution, A = Advisory, I = Informational

APPENDIX 6. RECOMMENDED SYMBOLOGY (FROM EMD MOPS)

The following table, Recommended Symbology, depicts the recommended symbology for use on electronic map displays. These symbols are from SAE ARP5289. Use of the recommended electronic symbols (right column) is highly encouraged. In the table above "T" is used for terminal and "E" is used for en route.

#	Symbol type	Jeppesen (T)	Jeppesen (E)	NOS/DMA (T)	NOS/DMA (E)	ICAO (T)	ICAO (E)	Boeing (T)	Boeing (E)	Airbus	Electronic Symbols Recommended by SAE ARP 5289
1	VOR										
2	DME										
3	TACAN										
4	VORDME										
5	VORTAC										
6	NDB										
19	Intersection									NA	
22	Waypoint									NA	
26	Airport									NA	



NOTE: It is recognized that fly-over and fly-by waypoint symbology is being used. No RTCA standard for fly-over and fly-by waypoints has been put forth since a standard set of symbols has not been internationally harmonized. For the recommended VOR symbol, the symbol does not need to be rotated. However, if another VOR symbol is used where North is indicated, it must be rotated.

APPENDIX 7. ABBREVIATIONS

The following abbreviations are recommended for the terms below, including checklists, messages, identification and labels for control functions. These abbreviations should not be used to represent any different term. These abbreviations should be used consistently in the pilot handbook supplements, quick reference checklists, on the equipment controls, displays, and associated labels (Reference RTCA DO-229B).

It is not the intent of this list to require upper case abbreviations, as many of these abbreviations may be clearly represented in a combination of upper and lower case type. In all cases the meaning should be easily construed and remain consistent in a given piece of equipment.

FIGURE 1. ABBREVIATIONS

DO-229B Word(s) To Be Abbreviated	DO-229B Recommended Abbreviation(s)	ICAO 8400/5 Recommended Abbreviation	ICAO 8400/5 Word(s) To Be Abbreviated
Acknowledge	ACK	ACK	Acknowledge
Active, Activate	ACT, ACTV	ACT	Active Or Activated Or Activity
Airport	APT	AP	Airport
Air Traffic Control	ATC	ATC	Air Traffic Control (In General)
Alert/Alerting	ALRT	ALR	Alerting (Message Type Designator)
Altitude	ALT	ALT	Altitude
Along-Track Distance	ATD		
Along-Track Error	ATE		
Along-Track	ATK		
Approach, Approach Control	APPR, APR	APCH	Approach
Area Navigation	RNAV	RNAV	Area Navigation
Arm, Armed	ARM		
Barometric Setting	BARO		
Bearing	BRG	BRG	Bearing
Cancel	CNCL	CNL	Cancel Or Cancelled
Center Runway	C	C	Centre (Runway Identification)
Centigrade	C	C	Celsius (Centigrade), Degrees
Clear	CLR	CLR	Clear(S) Or Cleared To... Or Clearance
Coordinated Universal Time	UTC	UTC	Coordinated Universal Time
Course	CRS		
Course Deviation Indicator	CDI		
Course To Fix	CF		
Cross-Track	XT, XTK		
Cross-Track Error	XTE		
Cursor	CRSR		

FIGURE 1. ABBREVIATIONS (continued)

DO-229B Word(s) To Be Abbreviated	DO-229B Recommended Abbreviation(s)	ICAO 8400/5 Recommended Abbreviation	ICAO 8400/5 Word(s) To Be Abbreviated
Database	DB		
Dead Reckoning	DR	DR	Dead Reckoning
Decision Altitude	DA	DA	Decision Altitude
Delete	DEL		
Departure, Departure Control	DEP	DEP	Depart Or Departure
Desired Track	DK, DTK		
Destination	DEST	DEST	Destination
Dilution Of Precision	DOP		
Direct, Direction	DIR	DCT	Direct (In Relation To Flight Plan Clearances And Type Of Approach)
Direct-To	direct symbol (D→) D with arrow		
Direct-To Fix	DF		
Distance	DIS, DIST	DIST	Distance
East	E	E	East Or Eastern Longitude
Emergency Safe Altitude	ESA		
En Route	ENR	ENR	En Route
En Route Safe Altitude	ESA		
Enter	ENT		
Estimated Time Of Arrival	ETA	ETA	Estimated Time Of Arrival Or Estimating Time Of Arrival
Estimated Time Of Departure	ETD	ETD	Estimated Time Of Departure Or Estimating Departure
Estimated Time En Route	ETE		
Fahrenheit	F		
Feet, Foot	', FT	FT	Feet (Dimensional Unit)
Feet Per Minute	FPM	FPM	Feet Per Minute
Final Approach Fix	FAF	FAF	Final Approach Fix
Final Approach Waypoint, For Waypoint Identifiers	f, FA, FAWP	FAP	Final Approach Point
Flight Level	FL	FL	Flight Level
Flight Plan	FPL	PLN	Flight Plan Cancellation (Message Type Designator)
From	FR	FM	From
Full-Scale Deflection	FSD		
Global Positioning System	GPS	GPS	Global Positioning System

FIGURE 1. ABBREVIATIONS (continued)

DO-229B Word(s) To Be Abbreviated	DO-229B Recommended Abbreviation(s)	ICAO 8400/5 Recommended Abbreviation	ICAO 8400/5 Word(s) To Be Abbreviated
Greenwich Mean Time	GMT		
Ground Speed	GS	GS	Ground Speed
Heading	HDG	HDG	Heading
Height Above Threshold	HAT		
		HGT	Height Above
Hold, Holding, Holding Pattern	HLD	HLDG	Holding
Horizontal Alert Limit	HAL		
Horizontal Protection Limit	HPL		
Horizontal Situation Indicator	HSI		
Horizontal Uncertainty Level	HUL		
Initial Approach Waypoint, For Waypoint Identifiers	i, IA, IAWP	IAF	Initial Approach Fix
Instrument Flight Rules	IFR	IFR	Instrument Flight Rules
Intermediate Waypoint	IWP		
Intersection	INT	INT	Intersection
Knots	KT		
Latitude	LAT	LAT	Latitude
Left	L, LFT		
Left Runway	L	L	Left (Runway Identification)
Localizer	LOC	LLZ	Localizer
Localizer-Type Directional Aid	LDA		
Longitude	LON	LONG	Longitude
Magnetic	M, MAG	MAG	Magnetic
		QRD	Magnetic Bearing
Mean Sea Level	MSL	MSL	Mean Sea Level
Message	MSG	MSG	Message
Meters	M	M	Meters (Preceded By Figures)
Military Operating Area	MOA	MOA	Military Operating Area
Millibars	mB		
Minimum Decision Altitude	MDA	MDA	Minimum Descent Altitude
Minimum En Route Altitude	MEA	MEA	Minimum
Minimum Safe Altitude	MSA	MSA	Minimum Sector Altitude
Missed-Approach	h, MH, MAHWP		

FIGURE 1. ABBREVIATIONS (continued)

DO-229B Word(s) To Be Abbreviated	DO-229B Recommended Abbreviation(s)	ICAO 8400/5 Recommended Abbreviation	ICAO 8400/5 Word(s) To Be Abbreviated
Holding Waypoint			
Missed-Approach Waypoint, For Waypoint Identifiers	m, MA, MAWP	MAPT	Missed Approach Point
Nautical Mile	nm, NM	NM	Nautical Miles
Nautical Miles Per Hour			
Nearest	NRST		
Non-Directional Beacon	NDB	NDB	Non-Directional Radio Beacon
Non-Precision Approach	NPA		
North	N	N	North Or Northern Latitude
Off Route Obstacle Clearance Altitude	OROCA		
Offset	OFST		
Omni-Bearing Selector	OBS		
Outer Marker	OM	OM	Outer Marker
Parallel Track	PTK		
Precision Approach	PA		
Present Position	PPOS, PP	PPSN	Present Position
Procedure	PROC	PROC	Procedure
Procedure Turn	PT	PTN	Procedure Turn
Radial	R, RAD	RDL	Radial
Radial/Distance	R/D		
Radius To Fix	RF		
Range	RNG	RG	Range (Lights)
Receiver Autonomous Integrity Monitoring	RAIM		
Relative Bearing	RB		
Required Navigation Performance	RNP	RNP	Required Navigation Performance
Reverse, Revision, Revise	REV		
Right	R, RT	RITE	Right Turn Of Direction
Right Runway	R	R	Right (Runway Identification)
Route	RTE	RTE	Route
Runway	RWY	RWY	Runway
Selective Availability	SA		
Sequence, Sequencing	SEQ		

FIGURE 1. ABBREVIATIONS (continued)

DO-229B Word(s) To Be Abbreviated	DO-229B Recommended Abbreviation(s)	ICAO 8400/5 Recommended Abbreviation	ICAO 8400/5 Word(s) To Be Abbreviated
Setup	SET		
South	S	S	South Or Southern Latitude
Special Use Airspace	SUA		
Standard Terminal Arrival Route	STAR	STAR	Standard Instrument Arrival
Suspend	SUSP		
Temperature	TEMP	T	Temperature
Test	TST		
Threshold Crossing Height	TCH		
Time To Alert	TTA		
To	TO	TO	To... (Place)
To/From	T/F		
Tower	TWR		
Track	TK, TRK	TR	Track
Track To Fix	TF		
Track Angle Error	TKE		
Transition Altitude	TA	TA	Transition Altitude
Transition Level	TL	TRL	Transition Level
True	T		
True Airspeed	TAS	TAS	True Airspeed
		QTE	True Bearing
True Heading	TH		
Variation	VAR		
Vector	VECT		
Vector To Final	VTF		
Vertical Navigation	VNAV, VNV		
Vertical Protection Level	VPL		
Vertical Speed	VS		
Vertical Track	VTK		
Vertical Track Error	VTE		
Vertical Uncertainty Level	VUL		
VHF Omni-Directional Range	VOR	VOR	VHF Omnidirectional Radio Range
Warning	WARN, WRN	WRNG	Warning
Waypoint	WPT		
West	W	W	West Or Western Longitude
Wide Area Augmentation System	WAAS		
World Geodetic System	WGS		